YEAR BOOK

OF THE

American Iron and Steel Institute

1915

MAY MEETING, NEW YORK
OCTOBER MEETING, CLEVELAND

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FOREWORD

This is the fifth Year Book of the American Iron and Steel Institute.

The first Year Book gave the proceedings of the International meeting which began in New York on Friday, October 14, 1910, and was continued in Buffalo, Chicago, Pittsburgh and Washington.

In 1911 the Institute held no general meetings.

The second Year Book gave the proceedings of the two general meetings held in 1912, the May meeting in New York and the October meeting in Pittsburgh.

The third Year Book gave the proceedings of the two general meetings held in 1913, the May meeting in New York and the October meeting in Chicago.

The fourth Year Book gave the proceedings of the two general meetings held in 1914, the May meeting in New York and the October meeting in Birmingham.

The present volume contains the proceedings of the two general meetings held in 1915, the May meeting in New York and the October meeting in Cleveland.

James T. McCleary,
Secretary.

TABLE OF CONTENTS

MAY MEETING

TABLE OF CONTENTS

OCTOBER MEETING

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AMERICAN IRON AND STEEL INSTITUTE

EIGHTH GENERAL MEETING

New York, May 28 and 29, 1915.

The Eighth General Meeting of the American Iron and Steel Institute was held at the Waldorf-Astoria Hotel, New York City, on Friday and Saturday, May 28 and 29, 1915.

Following the usual practice, three sessions were held on Friday. The forenoon and afternoon sessions, held in the Astor Gallery, were devoted entirely to the reading and discussion of papers. The evening session, including the annual dinner, was held in the Grand Ball Room. As usual, papers, discussions and addresses covered questions of metallurgy, of business and welfare work.

On Friday the secretary had a temporary office near the Astor Gallery where members registered for the meeting and were provided with identification buttons and with programs.

The paper read by Mr. Andrew E. Maccoun on Blast Furnace Advancement, that by Mr. Charles J. Bacon on Waste Heat Boilers, and that by Mr. Jerome R. George on Merchant Rolling Mills had been printed in advance in pamphlet form and were distributed to members for the respective meetings. Dr. Noland's paper at the evening session on Welfare Work of the Tennessee Coal, Iron & Railroad Company was illustrated by over fifty stereopticon views, some of which have been reproduced in this volume.

At the noon recess on Friday, the members of the Institute were its guests at a buffet luncheon and in the evening at the banquet. During this recess, also, the Directors held a Board Meeting.

As at previous meetings, the attendance was very large.

On the next page will be found the program of the Friday sessions, at all of which the President of the Institute, Judge Gary, presided.

FORENOON SESSION, 10:00 A. M.

Address by the President.............................ELBERT H. GARY

Informal Discussion under the Five-Minute Rule..........WILLIS L. KING
Vice-President, Jones & Laughlin Steel Company, Pittsburgh, Pa.

Blast Furnace Advancement......................ANDREW E. MACCOUN
Superintendent, Edgar Thomson Blast Furnaces, Carnegie Steel Company, Braddock, Pa.

Discussion.....................................AMBROSE N. DIEHL
Superintendent, Blast Furnaces, Carnegie Steel Company, Duquesne, Pa.

Merchant Rolling Mills............................JEROME R. GEORGE
Chief Engineer, Morgan Construction Company, Worcester, Mass.

AFTERNOON SESSION, 2:00 P. M.

The Commercial Production of Sound and Homogeneous Steel.......................................EDWARD F. KENNEY
Metallurgical Engineer, Cambria Steel Company, Johnstown, Pa.

Discussion.......................................HENRY M. HOWE
Professor-Emeritus of Metallurgy, Columbia University, New York, N. Y.

Waste Heat Boilers...............................CHARLES J. BACON
Steam Engineer, Illinois Steel Company, South Chicago, Ill.

Discussion..ROY A. LEWIS
Assistant General Superintendent, Bethlehem Steel Co., South Bethlehem, Pa.

Discussion.......................................DAVID S. JACOBUS
Advisory Engineer, Babcock & Wilcox Company, New York.

Recent Progress in Corrosion Resistance.................DANIEL M. BUCK
Metallurgical Engineer, American Sheet and Tin Plate Company, Pittsburgh, Pa.

Discussion..............................ALLERTON S. CUSHMAN
Director, The Institute of Industrial Research, Washington, D. C.

Discussion.......................................JAMES O. HANDY
Director of Chemical Laboratories, Pittsburgh Testing Laboratories, Pittsburgh, Pa.

Discussion.................................WILLIAM H. WALKER
Professor of Chemical Engineering, Massachusetts Institute of Technology, Boston, Mass.

Discussion...JOHN S. UNGER
Manager, Central Research Laboratory, Carnegie Steel Company, Duquesne, Pa.

Discussion.....................................GEORGE H. CHARLS
Vice-President, American Rolling Mill Company, Middletown, Ohio.

EVENING SESSION, 7:00 P. M.

ANNUAL DINNER

Welfare Work of the Tennessee Coal, Iron & Railroad Company......................................LLOYD NOLAND, M.D.
Superintendent of Health Department, T. C., I. & R. R. Co., Birmingham, Ala.

Impromptu Remarks in Response to Call of the President.

Remarks by the President............................ELBERT H. GARY

ADDRESS OF THE PRESIDENT

ELBERT H. GARY
Chairman, United States Steel Corporation, New York

On behalf of the Institute, I bid you welcome. The enthusiasm of the members of the Institute for the association and for each other is growing and is really wonderful. All of us, I am sure, derive much benefit and a great deal of happiness by reason of our association.

There has recently been manifested a disposition to blame the business men of the country for not openly and vigorously protesting against influences which were calculated to prevent the natural and reasonable progress of economic effort. Men of prominence and recognized ability have stated in unmeasured terms that it is not only the right but the duty of the business men to boldly and persistently advocate their claims and defend their rights. They have been charged with undue timidity for neglecting to appeal to the sense and fairness of the general public whenever assailed without good cause.

That there has been some ground for these criticisms will not be doubted; but there is another side to this question. The business man has not been alone in his seeming cowardice. There are others largely responsible for the general conditions, and therefore under obligations to work for the advancement of the public interest, who have been reluctant to express their real convictions. Reference is made to some of the statesmen of prominence and ability whose disposition for fair play is unquestioned. On occasions when their voices, if heard in legislative halls, would seem to have been influential, they have remained silent.

In times gone by there have been reasons for the hesitancy of the business man in boldly proclaiming his rights. The conduct of business by many men (though

small in number compared with the total) has not always been up to the standard of propriety. This is not a new subject; it has been frequently adverted to by many of us during the last ten years. As a consequence there has been considerable prejudice against business interests, particularly the larger ones; and it has been worse than useless to speak in favor of the protection and growth of business, for the words would be ineffective. So it is not difficult to understand why, for a period of years, business men in this country suffered in silence.

A Change for the Better.

There is no intention at this time to modify or minimize anything that has heretofore been said by way of admission that there was need of reform in business methods. On the contrary, the fact should be emphasized that we must be honest and fair in our treatment of all questions submitted to our consideration and decision. But as I have said before more than once, there has been in this country a decided change for better business methods and, therefore, in the attitude of the general public toward the men in charge of business. There never was any such disregard of the rights of others by business men generally as was frequently charged. It has always been the effort of the large majority to be decent; but all suffered more or less for the misconduct of a few. However, in recent years there has been little cause for complaint, and the general public understands and appreciates these conditions.

Now the time is come when the business man, even if he represents large interests, may speak frankly and freely about any of the important questions which affect him or those whom he represents. When and while our attitude and conduct are above reproach, others will be willing to heed what we may say concerning any question in which they or we may be interested. Indeed, as heretofore suggested, the leading newspapers of the country have been fair and reasonable in their advocacy of what-

ever makes for the advancement of the economic conditions of the United States and in their opposition to the efforts of unwise or unthinking or vicious men to the contrary. What follows in my remarks will be said from the viewpoint of those who may be directly connected with and particularly interested in the consideration of economic questions.

The material strength and growth of the nation is of high importance. Food, raiment and shelter are absolutely essential to the life and health of the individual. This is interwoven with all other questions. A nation of individuals who are poverty-stricken has little influence throughout the world. It cannot add much to the happiness of its citizens. If they are deprived of the necessities of life they will not listen long to the advocate of mere morals, nor to the speaker on the stump who seeks political preferment. It therefore behooves every one occupying a position of influence to give his best thought and endeavor to the promotion of business success in this country to the fullest extent consistent with propriety.

Some Reasons for Lack of Prosperity.

Attention is called to the attitude of governmental agencies during the last few years toward the business of the country and toward its attempts to develop trade. Has it been wise and judicious? Has it been fair and reasonable? Has it been broad and unbiased, or narrow and prejudicial? Has it been calculated to benefit all citizens alike?

With the advantages possessed by this country, on account of its location, climate, natural resources and immense wealth, it is not too much to insist that it should have been continuously more prosperous financially, commercially and industrially than any other nation on the face of the globe. Capital should have been protected, labor constantly employed at liberal wages, business enterprise encouraged, extensions and improvements continued without interruption, the wealth and population

should have increased more rapidly, and, as a result, all the people would have been happier and more contented and more generous toward each other. Moreover, the standing and influence of the nation throughout the world would have been improved. It is difficult to realize at this time what might have been accomplished if all the opportunities for reasonable success had been grasped.

But what can truthfully be said of business conditions in this country during the last ten years? Prosperity has often been interrupted; depressions have been frequent and severe; idleness has been noticeable and its results often distressing. Doubt, misfortune and fear have been prominent in business circles. Capital has been more or less timid and enterprise has hesitated. American investors, and more particularly foreigners with funds for investment have doubted the value of securities, which under some circumstances would be considered first-class, and have declined to purchase, and many have sold those already possessed. We have been the object of sympathy, and sometimes of ridicule, by the intelligent European financiers and economists. Words might be multiplied to illustrate the unfavorable conditions which have prevailed. It is true that various causes, some of which have been removed and ought never to have existed, have had a direct and important influence in producing adversity. This applies especially to conditions which the Federal Reserve Act, recently passed by Congress and now in force, was intended to remedy. This act seems to be generally considered as sound and valuable even though some amendments may be needed.

But the back of business has been badly bent with unnecessary burdens, and in fact has been near the breaking point. There has been an admonition against "Rocking the Boat," and we approve of the sentiment; but we submit the business men have not been rocking the boat. (Applause.)

The opinion is ventured that lack of continuous business prosperity and success in this country for a number

of years has, in part, been the direct result of undue, ill-considered or unjustifiable assaults which have been made by governmental agencies or by the erroneous and unwise policies of different branches of government. The results have shown to a demonstration that business success has not been fostered or encouraged as it ought to have been; that the vast possibilities of the country for increase in wealth have not been fully utilized. On the contrary, instead of trying to bring about cooperation between the Government and the people in a determined effort to better the conditions of all, there has been, in a substantial degree, an open hostility to business which has paralyzed many of its legitimate efforts. While, as heretofore admitted, there has been cause for complaint on the part of the Government, it is believed that few, if any, cases have been found which could not have been satisfactorily and properly adjusted by personal and friendly, though persistent, efforts without any open or advertised opposition which was certain to lessen confidence and to unfavorably affect large numbers in nowise connected with the matter in question.

It is not intended to be specific nor to do an injustice; but included in the terms used are speeches by men in office, the passage of laws that were discriminatory and others that were unwise or insufficient, investigations by committees appointed by Congress and legislatures, and by various departments and bureaus of government, including grand juries whose services were brought into action on special occasions by the Department of Justice. You who are present will make application of what has been said to individual acts, so far as the facts may warrant. Whether or not it is justified, there has been a feeling on the part of a large portion of the people of the United States, and also those of foreign countries, that there has not been a well-defined and persistent policy to cooperate with and to promote the interests of the business man to the full extent reasonable; and on the contrary, that the policies of some of the governmental

agencies, both national and state, in their effect at least, have been to interfere with, to delay and obstruct natural progress; to punish and destroy rather than to regulate and encourage. (Applause.)

Government Should Encourage Business Enterprise.

The time seems to be opportune, first, to reiterate that the business men throughout the country must give no cause for complaint in the management of their affairs, but must continue to live up to the standards of propriety; and, second, to insist that on those conditions the governments, with all their agencies and influences, shall cooperate with the business interests and aid them in establishing credit, in extending commerce, in increasing capacity, in the development of natural resources, in adding to the comfort of themselves and those with whom they may be connected and for whose welfare they are more or less responsible. If this shall be the recognized effort of the national and state Governments, what can we not properly say of the value of our property, of our future prosperity, the position of our credits, the stability of good conditions and the standing of our nation? And this attitude on the part of governments, we believe the people of this country are demanding and have a right to demand; and they will not be satisfied with less.

The people of foreign countries locate in the United States because, among other reasons, it is to their pecuniary benefit. The workingmen come here because they can obtain higher wages and better treatment. The employers have been doing what they could to justify the good opinions which the workmen have held; and so those in official authority must do everything practicable and proper to assist the employer. It will be difficult enough for productive interests in America, including both capital and labor, to compete successfully with foreign producers where governmental protection and assistance are afforded and labor is cheap, if we receive the cooperation which we claim we are entitled to.

Room for Improvement in Governmental Business Methods.

Again, may we not claim there is ground for improvement in the business methods of the national, state and municipal Governments throughout this country? There have been expenditures that were extravagant or useless, aggregating millions; unnecessary positions have been created; the number of incumbents multiplied; money has been paid out for decoration and display and for entertainment and personal comfort that were not appropriate nor justified in a country like ours, which should set an example for economy and efficiency; appropriations have been made for local improvements in order to secure personal patronage; also, to cover the expenditures of committees appointed by legislative branches and the Departments of Justice to pay for investigations, secret service, special counsel, etc. Some of the committees have devoted day after day to the examination of witnesses and the development of facts that were long before made public, thus adding without good reason to the enormous cost of printing the voluminous record. It is only necessary to hint at the uncalled-for expenditures of money, for you are all more or less familiar with them. Some day an enterprising newspaper will make such inquiry and examination as will enable it to publish, for the benefit of the reading public, the amounts of money which have been wasted by mismanagement, negligence or something worse. There is reason for believing that the estimate made by the late Senator Aldrich, of the amount which could be saved annually by the Government of the United States, if its affairs were conducted on a business basis, was conservative.

It is believed if the business methods of the United States Government and of its branches and departments were as careful and economical as those of many of the corporations whose presidents are listening to me at this time, hundreds of millions would be annually saved to the people of this country, portions of which are sadly

needed for other necessary purposes. Is it too much to ask that hereafter there be elected as legislators and officials of power none except those who possess, with other qualifications, business ability?

The stockholders of a corporation have no voice for the moment in the direction of corporate affairs, but their influence is nevertheless potential. So the masses of the people, represented by what is called public sentiment, sooner or later determine the policies of government; and they are at present protesting against wastefulness and extravagance and insisting upon the careful management and strict economy prevailing in the conduct of private affairs.

Need of Better National Defense.

In discussing questions relating to national expenditure, none of us would advocate limiting the amount required to be paid for the protection of the country, or the promotion of the welfare of the people. Disbursements of this character are not extravagant. We are rich, and, by the continuance of a proper policy, the wealth of the nation will rapidly increase, and we can, therefore, afford to expend whatever is actually necessary. This is true economy, and in the end results in a great saving of capital.

Apropos to this subject, it may be said we should create and maintain an adequate army and navy. We are deficient in this respect. We have an effective navy, but its capacity is much below the standard that should be maintained. There have been differences of opinion in Congress whenever the question of enlarging the army and navy has been presented for discussion, and no doubt all those giving expression to their conclusions have intended to be honest. However, it is possible that not uncommonly a member of Congress has been willing to vote for a large appropriation to provide a local improvement in which he was particularly interested and at the same time has opposed the building of an additional ship or the equipment of another regiment.

We should especially maintain a better navy—one equal, at least, in every respect to that of any other nation. So far as the army is concerned, a comparatively small number of regular troops together with a large force of reserves, properly trained, with adequate supplies for use in times of emergency, such as General Wood and others advocate, would probably be sufficient. But we should be prepared at all times to protect our borders on the sea and also our commerce wherever it extends. The nation with an inadequate navy must always labor at a great disadvantage with respect to its commerce in times of trouble, or even in times of peace. The protection of our property and our business is essential, and can only be secured if we maintain a large navy, which shall include the most efficient personnel and the very best of ships and equipment. It is not necessary to recall the many reasons for a large navy. There is apparent unanimity of opinion at present that we should proceed in this direction systematically and vigorously. We have been inexcusably negligent in this respect. Business men generally have favored every proposed appropriation for this purpose.

After the troubles growing out of the European war are over, there will be a general struggle, however good-natured, for export business. Our exports should materially increase, and large numbers of ships flying the American flag should be placed in service, and they will be if appropriate governmental encouragement is extended. Ownership by the Government is not alluded to. We must not remain in a position which permits the navy of any other individual country to dominate the seas. Whatever the disposition and intention of the rulers of other nations or those in high authority may be, there would be occasions when arbitrary action by local officials coming in contact with those pecuniarily interested in a special question, precipitated by circumstances, might be very detrimental to the interests of an American merchantman involved. We have reached a position of great power throughout the world, and this will be even more

potential if we are prepared physically to make good our assertions in favor of the fair treatment of all matters we are called upon to decide. We must demand and insure the right to transport our goods freely across the seas, and further, that all seaports shall be kept open for the delivery and receipt of every merchantable commodity.

Our country must never provoke controversy nor act from selfish or immoral motives. We love peace and we hate war, but under present conditions, which it is to be hoped may speedily change, we must be prepared to defend our rights. We will be just and even generous, but we will not shirk obligations we are under to ourselves or to others. Without an adequate navy we may expect to be sneered at by other nations in time of crisis. Even this we might endure; but some time, when least expected, we may be imposed upon beyond endurance. We should keep the olive-branch extended in front so long as possible, but when it is smitten from our hands without cause or provocation by an unfriendly power that seeks to destroy us, we should, so long as present methods are in vogue, be prepared to protect ourselves. (Applause.)

Our Normal Trade with Countries Now at War.

The business relations between the United States and foreign countries before and after the war are important to be considered at this time in connection with the paramount topic of the day, namely, the attitude which should be assumed and maintained by this country. The business men are tremendously interested in this question, and it is growing and will continue to grow in importance during the next few months. Figures bearing upon this subject are illuminating and instructive. The commerce between the United States and Austria-Hungary, Belgium, France, Germany, Great Britain, Italy, and Russia in Europe, respectively, for the fiscal years ending June 30, 1910, to June 30, 1914, inclusive, were in round numbers, as follows:

	Exports to	Imports from	Balance Exports over Imports
Austria-Hungary			
1910..........	$14,962,731	$17,408,910	*$2,446,179*
1911..........	19,514,787	16,958,099	2,556,688
1912..........	22,388,930	16,713,794	5,675,136
1913..........	23,320,696	19,192,414	4,128,282
1914..........	22,304,654	20,110,834	2,193,820
	$102,491,798	$90,384,051	$12,107,747
Belgium			
1910..........	$41,116,585	$40,059,281	$1,057,304
1911..........	45,016,622	37,084,743	7,931,879
1912..........	51,387,618	41,677,418	9,710,200
1913..........	66,845,462	41,941,014	24,904,448
1914..........	59,506,535	41,035,532	18,471,003
	$263,872,822	$201,797,988	$62,074,834
France			
1910..........	$117,627,466	$132,363,346	*$14,735,880*
1911..........	135,271,648	115,414,784	19,856,864
1912..........	135,388,851	124,548,458	10,840,393
1913..........	146,100,201	136,877,990	9,222,211
1914..........	155,591,287	141,446,252	14,145,035
	$689,979,453	$650,652,830	$39,328,623
Germany			
1910..........	$249,555,926	$168,805,137	$80,750,789
1911..........	287,495,814	163,242,560	124,253,254
1912..........	306,959,021	171,380,380	135,578,641
1913..........	331,684,212	188,963,071	142,721,141
1914..........	341,875,820	189,919,136	151,956,684
	$1,517,570,793	$882,310,284	$635,260,509
Great Britain			
1910..........	$505,552,871	$271,029,772	$234,523,099
1911..........	576,613,974	261,289,106	315,324,868
1912..........	564,372,186	272,940,700	291,431,486
1913..........	597,149,059	295,564,940	301,584,119
1914..........	590,387,927	293,661,304	296,726,623
	$2,834,076,017	$1,394,485,822	$1,439,690,195
Italy			
1910..........	$53,467,053	$49,868,367	$3,598,686
1911..........	60,580,766	47,334,809	13,245,957
1912..........	65,261,268	48,028,529	17,232,739
1913..........	76,285,278	54,107,364	22,177,914
1914..........	73,737,526	56,407,671	17,329,855
	$339,331,891	$255,748,740	$83,585,151
Russia in Europe			
1910..........	$16,789,930	$16,196,154	$593,776
1911..........	23,524,267	11,004,164	12,520,103
1912..........	21,515,660	20,666,923	848,737
1913..........	25,363,795	26,958,690	*1,594,895*
1914..........	30,039,887	20,831,184	9,208,703
	$117,233,539	$95,657,115	$21,576,424

Thus it will be seen that, for a period of five years, the total business so far as reported between the United States and all of these countries, in money value, aggregated $9,435,593,143, and the balance of exports over imports amounted to $2,293,623,483.

We would be dull of conception if we failed to comprehend the importance of these trade relations; and any act on our part which might tend to sever the connections, or any of them, or to interfere with their natural growth, should be condemned as unworthy and unintelligent. For many years we have been striving to cultivate a spirit of friendship and confidence with our brethren across the seas, because, among other reasons, we realize it is for our pecuniary benefit. This has been especially true of the iron and steel interests, and, except for unreasonable and partisan criticisms, not necessary now to locate, much could have been done along legitimate lines to make further progress in the establishment of a permanent international basis of business friendship, which would be of advantage to all and of injury to none. It is sufficient to say that our trade with foreign nations has been increasing, with prospects for more rapid and larger advances and with the expectation of the balances in favor of the United States becoming augmented from year to year. I do not, of course, refer to the volume of business at the present time, for it is abnormal.

When Peace Shall Have Returned.

The belligerent nations involved in the tragedy of tragedies are passing through a cataclysm of destruction of life and property. Their losses in both respects are beyond our knowledge and even our comprehension. Devastation, misery and suffering are beyond description; even those connected with the participants by ties of relationship or otherwise have slight comprehension of the suffering that is being endured; and we at this distance cannot imagine the ruin, damage, pain and distress which are entailed. After the swords are sheathed

and the guns are stacked; after the hideous noises of battle have ceased and the nations now involved in desperate struggle are ready for settlement, they will be confronted with many most difficult problems, the solution of which will require time and patience, so that the natural progress toward rehabilitation will be impeded. The people, as distinguished from the rulers, will have a voice in bringing the war to a close and in the settlements which are to be made. The doctrine of "the divine right of kings" will be only a recollection. It is a good guess that many kings and kingdoms will be occupying space on the Transition Slide.

But after all differences are adjusted, the nations now or to be engaged in this colossal conflict, though terribly crippled, will take a new start and in many respects a new course, and will begin immediately to build on a better and firmer and more permanent basis for success and high achievement in everything that adds to national wealth, power, energy and enterprise. These nations will not remain inactive or despondent or indifferent. We shall see the most active and persistent efforts to rebuild and extend and to succeed in the international race for supremacy that the world has ever witnessed. From adversity will come greater prosperity than ever before. From necessity will spring thought and study and effort that will enable the survivors to reach greater heights of success than has been supposed to be within the reach of humankind. The peoples of all the different countries, suffering in their thoughts of the past, will be inspired to greater exertions in their efforts for the future. It is not too much to believe that, after the close of the war, there will be a feeling almost universal that there must be established and maintained a court of arbitration—simple, comprehensive, effective and permanent—that will secure the adjustment of all future differences without any protracted or general contest by armed forces. A majority of the nations will, to use an ordinary paradox, "secure and maintain peace if they have to fight for it."

Now, what should the United States prepare for? If we conduct our affairs properly, if we make the most of our opportunities, if we cooperate with one another, if the Government and governmental agencies and the business people are allies one with the other, we shall become stronger and richer and more potential in our influence, and we shall be able to take a place in the van of nations, progressing toward results more satisfactory than ever before. I made the statement long before the war, and I have made it since, that we might become the leading nation in finance, commerce and industry. I have recently read statements by financiers that we already occupy this position. I do not quite agree with this claim, notwithstanding what has occurred in Europe during the last year; that is, I do not think we are thus permanently established; but it seems certain that we may accomplish this result if we properly conserve our resources. We may hold either a primary or a secondary place, depending upon the wisdom, energy and discretion of our people. Much depends upon our management of affairs. There has never in the history of the world been so great a necessity for wise and disinterested statesmanship or for loyal and honorable conduct on the part of the practical business men as at present. Will we do our part? Are we ready to devote our time, our attention and our energies in the performance of our patriotic duty?

We Must Maintain Our Neutrality.

In connection with this subject, it is natural to consider the question of neutrality on the part of our nation toward each of the belligerent nations. Probably all of us will agree that, up to the present time, the attitude of the President with respect to this question has been admirable. He has shown himself to be a true patriot and a wise statesman. In my opinion, the United States has not been called upon to do or to say anything with reference to the war or any of the participants which has

not been said or done. Every duty devolving upon the United States has been performed. We may have sympathies or prejudices or notions concerning specific acts or expressions on the part of some or many of the foreign nations, but, in my judgment, they have not required and do not require any act or expression on our part which has not been done or made. We have fulfilled every obligation imposed upon us by all treaties or agreements expressed or implied. When the questions which have been discussed and the final and logical conclusion shall have been reached in the light of all the evidence, including the full history of the transactions involved, I think it will be found my statement is fully justified. It is to be hoped, and I think we may expect, that nothing will occur to disturb the international relations existing at the present time between the United States and each of the foreign nations. It is unthinkable that we should become involved in war with any of the foreign countries at this time. We have no inclination, nor have we the ability, to engage in war. We can prepare, and we should prepare as rapidly as possible, so that if obliged to defend ourselves we cannot be overcome. Some of the belligerent nations are now suffering because their soldiers are not furnished with adequate equipment or supplies. They were not prepared at the beginning of hostilities, perhaps because war was not expected; but even so, they probably did not immediately after war was declared use the diligence required to supply their necessities as they now appear. We may learn by their misfortunes. But war should be the last resort. When the present combat shall have ceased we must be on a friendly footing with all the nations. If our financial and business conditions are such as we claim they may and ought to be, we may be profitable customers of each of the foreign nations, in supplying our necessities and comforts, and they in turn will patronize us. There will be, no doubt, vigorous competition, and the foreign nations will do their utmost to secure and retain the trade of agricultural countries who

are large importers of manufactured products. However, it is not active competition we fear, provided we are properly protected by our Government. All we need and all we ask is an open field and a fair chance, on an equal basis, to compete with all nations for a reasonable share of the world's business. We extend to the people of all foreign countries the hand of business friendship, and we ask for their friendship in return. And we ask for similar reciprocal relations between the leading political forces of the United States and ourselves to the full extent that we deserve.

Competition with cooperation is desirable. Competition is, or should be, healthful; but cooperation, which benefits all concerned and injures none, is perfection of economic health and progress. Argument in favor of competition, without recognition of the principle of cooperation, is theoretic and academic, and is neither wise nor practical.

In the last analysis, the conclusion will be reached by the vast majorities that the best interests of the peoples of all nations will be promoted if the present international equilibrium is substantially preserved. The destruction of any nation would be detrimental to the best interests of all others.

The Business Outlook.

I will add a few words in regard to present business conditions. As you know, during the last three years I have not been especially encouraged as to the immediate future, but as to the long future I have been a consistent optimist, for reasons which have been given from time to time. Assuredly we may build our hopes and expectations on the opportunities which this country offers. It seems to me at the moment the outlook for improvement in our lines of activity are better than they have been for more than a year. This is undoubtedly in part the result of increased exportations at fair prices, due to the European wars, but in my opinion also because of a

change in sentiment toward business, which now seems apparent.

The captain of industry is again to be popular in the United States, and this has been brought about by the efforts of business men to satisfy the public in regard to their reasonable demands. The individual, or aggregation of individuals, or the nation, whose standard of conduct conforms to the golden rule will on the average secure the largest pecuniary success.

The clouds of distress, suspicion and hostility are breaking. In the rift we may see the sunlight of better things and better conditions. (Applause.)

In closing I quote from the speech of Mr. Robinson at Chicago in presenting for your consideration a design, afterward adopted by you as the seal of this Institute, the sentiments of which influence all of our deliberations:

"In its detail this seal shows you the sword and the spear transfused by the alchemy of wisdom into the plowshare and the pruning-hook.

"The crucible represents the birth of steel, the steel of War and the steel of Peace; but these simply surround the central motif, the Spirit of Cooperation symbolized by the bird of Immortality, the Phœnix, rising from the ashes of Discord, Enmity and Strife into the rays of Enlightened Life.

"In its finality, the seal, bound by the sturdy oak and wreathed with leaves of olive, forms, perhaps, a fitting laurel to the strength of unity and the gospel of cooperation." (Applause.)

President Gary: The directors of this Institute decided they would give more opportunity at this meeting, if not at all meetings in the future, to discuss the addresses that are to be made or the papers that are to be read, and I suggested that it would be only fair to allow people to take a fling, so to speak, at the President's address, as he did not assume to have the right to express the sentiments of the whole body. And so opportunity is going to be given you now to discuss briefly, if you

please, the address which the President has made, and I will ask any one who will be willing to say something to take up the subject and say what he pleases about it.

Discussion by Willis L. King

Vice-President, Jones & Laughlin Steel Company,
Pittsburgh.

It seems almost out of place for me, Mr. Chairman, to criticize your calm, judicial and many-sided exposition of the conditions all over the world. I must confess, however, that there have been many times, in the last few years, when I felt that the business men of this country were remiss in not telling to the great public some of the handicaps they labored under. I am satisfied now that yours was the right policy, partly, I think, because I believe we are nearly at the end of our troubles. If I have any criticism to make of the President's paper, I would say that he is less optimistic than he might be, even of the near future. The conditions seem to me wonderfully ripe for an early resumption of business; in fact, I think the turn has come. For the first time in our history we can say that we have the world for a market. That is one great thing; and, I believe, even after the war, we will retain very many of the markets we are getting now. In the second place, the financial conditions and the increasing balance of trade are assured, but, best of all, the crops promise the largest harvest in our history for many years. Taking all those things into consideration, I believe we may be not only conservatively hopeful but optimistic. (Applause.)

President Gary: Are there others? Do not hesitate, gentlemen; we shall be very glad to hear from any of you. (After a pause. We shall now have a paper on Blast Furnace Advancement by Mr. Andrew E. Maccoun.

BLAST FURNACE ADVANCEMENT

A. E. Maccoun
Superintendent of Edgar Thomson Furnaces, Carnegie Steel Company

In the last few years many very interesting and instructive papers by blast furnace operators have been written describing various details of this subject, and read before the American Iron and Steel Institute, the American Institute of Mining Engineers, and other technical societies. These studies for the most part are devoted to separate details; consequently it is impossible for me in a short space of time to review the entire subject as thoroughly as it should be covered.

The historical development of the blast furnace and the theory of the process have been touched on very briefly, as these have been fully covered in the technical literature devoted to the subject.

I have, however, endeavored to cover briefly some of the important details that are of interest to blast furnace operators, but under the sections devoted to the "Balance Sheet of a Blast Furnace," and to "The Use and Theory of Hot Blast," I have elaborated more or less, and given extracts from two very complete tests made under the supervision of the Operating Department of the Edgar Thomson Furnaces of the Carnegie Steel Company. This has been done not only because I consider these tests in themselves especially interesting, but because they emphasize the importance of combining the various thermal processes in series in the final summary, "Future Developments in Blast Furnace Practice."

The production of iron in the blast furnace is at the present time the most efficient of all metallurgical processes in the utilization of heat, but we may look for a still further increase in this efficiency in the future.

One of the most important factors from which we are to obtain this increased efficiency is in the maximum utilization of the energy contained in the blast furnace gases, and it is to this part of the subject in particular that we will devote most of this study.

Greater efficiency in the use of blast furnace gases, new labor-saving machinery, and devices for obtaining more regular operation, such as distribution, greater uniformity of material, blast, etc., will not only help to increase and improve the product, but will also decrease the cost of production, as these conditions go hand in hand. To obtain these results is the aim of all blast furnace managers.

RAW MATERIALS FOR USE IN THE BLAST FURNACE.

To obtain successful blast furnace practice too much importance cannot be given to the uniformity, both chemical and physical, of all the materials entering into the manufacture of iron. This includes not only ore, coke, and limestone, but the blast used for the furnace as well. It is very important that the moisture content of the air be low, and at the same time uniform, in order to obtain regular results.

Iron Ores.

The ores of the Lake Superior District, Bessemer and non-Bessemer, of the Marquette, Menominee, Gogebic, Vermillion, and the Mesaba ranges, while varying in some respects, are as a rule similar in contents, physical characteristics, and structure. It is this class of ores, known as fine ores, upon which our experience in the Pittsburgh District has been principally based. In studying this paper it is well to keep this in mind, as some of the conditions described would no doubt be different on furnaces using a different class of raw materials.

The desirability of an ore for a blast furnace is based

on the percentages of its various ingredients, physical characteristics and structure, lump value, density, porosity, availability, and to some extent on its degree of oxidation. The percentage of natural iron content is the important governing factor in all ore values, while the amount of moisture contained in the natural state has considerable bearing on the ultimate cost. If the material is to be transported to any distance, this point is so important that in some cases it is very profitable to dry the ore before shipment from the mines.

The quantity of rich ores available is decreasing, leaving leaner ores, which are not so desirable. Great progress is being made in the preliminary treatment of these materials by the various concentrating processes. Iron ores are now washed which a short time ago did not seem amenable to this process; ores that contain excessive water have their moisture removed by drying; the magnetic concentration of magnetites is being done at very low cost; also pneumatic concentration of haematites is being commercially accomplished and will be still further developed. Some of these products can be used directly in the blast furnace without further treatment, but when too fine they must be either briquetted, nodulized, or sintered by some of the well-known processes. Important savings are being made in the treatment of blast furnace flue dust, which was formerly a waste product, by means of all of these various processes, so that in modern practice there should be comparatively small losses from this source. It is impossible, however, to go into this interesting subject further, as it is a study in itself. Great progress has been made in mining, mixing, and classifying the various Lake Superior ores, depending on their different contents and physical structure. Progress along these lines is very important, and helps to greater uniformity in blast furnace practice. Frequently there are large variations in ores from the same mine.

Large lumps of ore should be crushed as they injure

distribution and very often arrive at the tuyeres in an unreduced state, requiring an excessive amount of carbon for direct reduction. Nor is it advisable to have ores of different degrees of oxidation in the same burden. However, it is often profitable to use a limited amount of materials hard to reduce in the burden, such as the various kinds of cinders, etc., but such are used only on account of their low cost, or when operating conditions indicate that their use will benefit the furnace locally.

Blast Furnace Coke.

Every effort is being made to attain low fuel economy in blast furnace practice by perfecting distribution, furnace lines, and improving the quality of coke, ore, and limestone used in the burden.

Fixed Carbon is alone efficient as fuel in a blast furnace.

A great proportion of our blast furnace trouble comes from the use of dirty coke or coke of poor quality. The former condition is always due to carelessness in its manufacture; too much stress cannot be given to this point. Coke should be thoroughly screened at the ovens as well as at the furnace bins. It is foolish to expect to get fuel value out of coke breeze and the small dirty screenings which accompany poorly prepared coke.

Coke dust contains a large proportion of the ash, sulphur, phosphorus, and other impurities contained in the coke, and on account of its fineness and its tendency to cause a furnace to scaffold adds additional irregularities to furnace operations. As the amount of dust received with shipments of coke is not constant, but varies greatly at times, it is impossible to properly burden the furnace to offset the effects of this objectionable material. The impurities in the coke dust, therefore, are detrimental to the quality of iron produced and the coke practice, as well as making the furnace work irregularly, causing slipping, etc.

Some analyses of coke dust are given below. From

these results it can be seen that this material is very bad and utterly unsuited to obtain uniformity in blast furnace practice.

ANALYSIS OF DRY COKE DUST.

Fixed Carbon.	Volatile Matter.	Ash.	Sulphur.
68.60%	3.00%	28.40%	.961%
71.40	3.20	25.40	1.125
71.15	3.25	25.60	1.250

As mentioned before, only the fixed carbon is efficient for a blast furnace, and not all of that, because the ash of the fuel needs to be fluxed, and a certain amount of fixed carbon will be required to be burned to simply melt this slag.

It must also be borne in mind that the ash requires one and one-half times its weight of stone, and the sulphur over three times its weight of stone to neutralize or flux it, irrespective of the total amount of sulphur to be taken up by the slag. If an excessive amount of sulphur be present it is necessary to provide means for its removal, which, in case the limit of blast temperature has been reached, will require an increase in slag volume which can be obtained only at the price of higher coke and limestone consumption. It must also be borne in mind that the weight of slag produced requires 25 per cent. of its weight of carbon to melt it. Thus it can be seen how important it is to reduce the sulphur and ash in the coke as much as possible if we are to obtain good results.

The best bee-hive coke suitable for blast furnace use is distinguished by hardness, the power of resisting a crushing load, and an almost metallic lustre, together with freedom from slate enclosures, which raise the ash content; while the worst is the soft, dark colored and pulverulent variety known as "black ends."

Charging material of this kind practically results in adding coke dust to the furnace burden. This fine coke dust is acted upon by the CO_2 from the reduction of the ore, changing it to CO and dissolving the fine carbon. This action takes place at all temperatures above 710° F., and causes a large loss.

The black ends and coke dust contain most of the volatile matter and at the same time, on account of their porous nature, absorb and retain a much greater quantity of the water used in quenching than the denser varieties of coke.

By-Product Coke.

The use of by-product coke as a blast furnace fuel has made great advances in this country in the last few years, and it is now one of our most important considerations even in the Pittsburgh District, and is of still greater importance to furnaces located at a distance from the mines.

From a conservation standpoint we have little reason to be satisfied with the crude and unscientific manner in which bee-hive coke operations are conducted, and even leaving out this consideration there is a large profit on the side of using by-product coke. This coke, as now manufactured at our modern plants, is superior to the Connellsville coke for blast furnace use, on account of its uniformity in size, weight, and analysis. In addition the valuable by-products are recovered, such as coke oven gas, tar, ammonium sulphate, and benzol.

At first by-product coke burned slowly at the tuyeres of a blast furnace, retarding the speed of melting, and carrying the heat too high up in the furnace stack, and on this account was not favored by blast furnace operators. This has been remedied by the use of higher blast temperatures, by using perfectly screened coke, by breaking it smaller, and by regulating its manufacture in many other ways to secure the proper combustibility, so as not to slow down the driving of the furnace.

Progress is being made in washing coal in order to lower the sulphur content, while promising results have also been obtained from pneumatic separators. There will be further development along these lines in the future, as the advantages of using coke low in sulphur and ash in a blast furnace are now fully appreciated.

I would refer anyone who desires to pursue this study further to Mr. C. A. Meissner's interesting paper on by-product coke read before the American Iron and Steel Institute, September 23, 1913, and Mr. W. H. Blauvelt's papers read before the American Iron and Steel Institute, May 22, 1914, and the American Institute of Mining Engineers, October, 1912.

Limestone.

The limestone used as a flux in a blast furnace should be selected with great care, as many blast furnace troubles are due to irregularities in composition and size of the limestone used.

Limestone should be thoroughly screened, and in some cases washed, and should not be too large, as large lumps impair the distribution, and often come to the tuyeres unburned, requiring large quantities of heat. It is hardly necessary to point out the injurious effects of such lumps of corrosive basic material on the lining, or the fact that to obtain the greatest fluxing efficiency and smoothness of working, the lime should be burned while intimately mixed with the ore and coke it is intended to flux. The fines in limestone contain very objectionable impurities, as does the coke dust, and they are especiallly harmful when charged into a furnace irregularly, and in large quantities. A good stone should not contain fines that could be removed by a 1″ square screen, and should be fairly uniform in size, passing through a 6″ ring. It should be screened, and not contain any clayey material. The available base should be as high as possible.

It is important in our practice, with ores averaging about 7.5 per cent. silica, that the limestone be as low and regular in silica content as possible, so as to get more uniform results. It can be shown that each decrease of 1 per cent. silica between 5 per cent. and 1 per cent. amounts to a reduction in cost of approximately 10 cents per ton of limestone. It represents a saving in coke, increased production, and necessarily lower operating cost.

In our Bessemer and basic practice we have found the use of calcite preferable, but on spiegel and ferro-manganese, a mixture of one-half calcite and one-half dolomite gives better results, as it gives a more fluid cinder, allows us to run a more basic slag, and thereby keeps the manganese loss lower.

On the assumption that all silica is fluxed in the ratio of 1.00 to 1.35 per cent. silica to base, the following is true:

Low Silica Stone.

CaO and MgO present by analysis	55.40%
To flux 1.00% silica at 1.35 ratio	1.35 CaO and MgO
Available base	54.05%

High Silica Stone.

CaO and MgO present by analysis	52.75%
To flux 5.00% silica at 1.35 ratio	6.75 CaO and MgO
Available base	46.00%

Comparing the low silica stone with the high silica stone, we find a difference of 8 per cent. in available base, which is equivalent to an increased efficiency of approximately 17 per cent.

AIR SUPPLIED TO A BLAST FURNACE.

Nearly 60 per cent. by weight of the materials going into a blast furnace is air. The moisture in the air blown into a blast furnace has long been recognized as a very important item affecting the manufacture of iron. Many methods have been proposed for its removal, but the most successful process that I know at the present time is the Gayley dry blast process. It is true that there is a great deal of complicated machinery, etc., connected with this process, but it will be simplified more and more with newer installations, and the cost of installation and operation will no doubt be greatly reduced.

I have taken the following data from Mr. Gayley's important paper on this subject.

"A modern furnace consumes about 40,000 cu. ft. of

air per minute, and for each grain of moisture per cubic foot there enters the furnace one gallon of water per hour for each 1000 cu. ft.; that is, if the moisture was one grain per cu. ft., 40 gallons of water would enter the furnace per hour. The variation of moisture from month to month in the Pittsburgh District is shown in the following table":

	Average Temperature, Degrees F.	Weight of Water per Cubic Foot of Air, Grains.	Quantity of Water Entering per Hour into a Furnace Using 40,000 Cu. Ft. of Air per Minute. Gallons.
January	37.0	2.18	87.2
February	31.7	1.83	73.2
March	47.0	3.40	136.0
April	51.0	3.00	120.0
May	61.6	4.80	192.0
June	71.6	5.94	237.6
July	76.2	5.60	224.0
August	73.6	5.16	206.4
September	70.4	5.68	227.2
October	56.4	4.00	160.0
November	40.4	2.35	94.0
December	36.6	2.25	90.0

Keeping this in mind while studying the heat balance which is to follow will greatly aid us in understanding the savings that can be expected from the use of dry blast. We will refer to this process later.

In connection with the dry blast process or the use of natural blast, special consideration should be given to the air supplied to a blast furnace and its increase in volume with its rise in temperature, and the weight of oxygen furnished, for it is the oxygen that enters into combustion with the coke and the amount supplied should be nearly constant.

THE BLAST FURNACE AND ITS ACCESSORIES.

A great amount of study has been expended on blast furnace construction, not only towards improving the quality of the product and reducing the operating expenses and cost of production as much as possible, but in

an endeavor to make this class of work safer and more pleasant for the men employed.

To secure the most regular working in the furnace the materials should be as uniform as possible in composition. With the ores used, this is done before shipment by a very thorough system of mixing, so that the resultant material shows only slight variations during the entire season. The various cargoes of each particular ore further undergo an additional mixing as they are unloaded into the furnace stock piles by the ore bridges, so that any portion of the pile may be fairly considered as representative of the season's average ore shipments. This system results in the elimination of one of the variable conditions confronting the furnaceman, due to irregular analysis of ore, and helps greatly in attaining uniform operation.

In order to still further aid in obtaining a more uniform mixture, both chemically and physically, bin systems of the most improved type are being adopted for ore, coke, and limestone.

The importance of many of these refinements has necessarily come from having to use large percentages of Mesaba ores in our burdens.

Mesaba ores being very easy to reduce, it follows that when carrying a large percentage of these fine ores the greatest care must be given to distribute them to the best advantage in a furnace burden. Owing to the tendency of the fine Mesaba ores to pack closely, the ascending gases do not percolate through the burden readily, and try to find as easy passages as possible. When this takes place the ascending gases do not come in contact with the ores evenly over the whole surface across the horizontal sections of the furnace, and some of the ore will not be thoroughly reduced by the gases. This will cause an increased coke consumption on account of the carbon required to reduce this ore, because it requires partial direct reduction. These irregularities are also augmented by any irregularities in charging or the

arrival of large quantities of material in a state of fine mechanical division, giving rise to an interruption in the uniform upward flow of the gases. This is one of the important reasons why soft coke, coke dust, limestone dust, etc., should be thoroughly eliminated.

In considering the present trend of operating practice and construction, I can only point out briefly some of the important items for consideration.

Methods for unloading ore in bins and stock piles have been greatly improved, effecting a reduction in operating cost and eliminating hard and laborious hand labor. This is accomplished on inland furnaces by means of car dumpers, ore bridges, and systems of automatic-dump motor-driven transfer cars carrying ore to stock piles or furnace bins, etc.; and on Lake furnaces by Hewlett unloaders, or fast plants in connection with ore bridges, which are used in transferring ore from vessels to stock piles and furnace bins.

The modern bins are of very large capacity so as to obtain better mixing and to have plenty of materials on hand in case there is any temporary shortage in the supply of the raw materials. There is also an advantage in not requiring an unloading force on the trestle during the night shifts.

There should be at least two, preferably three, unloading tracks over the top of the bins, one of these tracks being used for transfer car service, the bins being arranged in sections of suitable length for dumping cars, and designed so that there is no tendency to the segregation of the coarse and fine materials in the bin itself, or in drawing the stock from the bin chutes into larry cars.

Large capacity larry cars are used between bins and skips with recording scales to obtain more accurate weighing. Greater uniformity and economy in both labor and power is obtained with the large larry, on account of the fewer number of trips required. In some cases a modern larry car will hold a full charge of ore and limestone.

Furnace stacks having a lining of moderate thickness, approximately 36″, are preferred. The thin-lined stack has not been, on the whole, as successful as was hoped for.

Furnace shells of heavy riveted steel plate construction are being used, and downcomers and dust catchers are being greatly increased in strength. Linings are laid directly against the shell and no packing space is used, as formerly, to take care of the expansion of the brickwork.

Hearth and bosh construction has been greatly strengthened and improved upon. Very much more substantial hearth jackets are being used. They are strong enough to resist the expansion of brickwork, made absolutely tight, thoroughly water cooled; as a result they almost eliminate the danger of severe breakouts. Ditches around hearth jackets have been found objectionable.

The bosh usually preferred for large Mesaba furnaces is protected by bronze cooling plates and heavily banded to supply the necessary strength. An over-cooled bosh is very objectionable, as it is often responsible for poor furnace practice. On large Mesaba furnaces the water cooled steel plate bosh with sprays or buckets has not given good results.

Bosh angles have become steeper and shorter, making a quicker descent for the charge. Distances of tuyeres above cinder notch have been increased slightly to advantage.

Protection for the inwall of a furnace by cooling plates has shown itself to be very beneficial in many cases. Furnace "I", which was so protected, of the Edgar Thomson Furnaces, which will be referred to later, produced 1,200,000 tons on her last lining. We do not claim that these plates hold the furnace lines absolutely, nor do we think this to be desirable in some cases; but we claim that this cooling helps to extract some of the heat from the inwall, thereby increasing its resisting qualities to heat and to erosion by the gases. The batter of furnace stacks has been increased, and is now preferably as near eight-tenths of an inch to a foot as possible.

Studies have been made of the quality of fire brick best suited for furnace linings, their resistance to erosion by the furnace gases, and abrasion by the stock. In this connection porosity, density, melting point, conductivity, abrasion, and spalling tests have been made, and the effects studied of various percentages of calcined flint, flint, and plastic clays, together with the influence of the weathering, grinding, and coarseness of material in relation to the above qualities.

Stock line protection is being secured by the use of many good arrangements which are giving excellent satisfaction.

Bells and hoppers are designed that give no trouble through the campaign of a furnace. Large bells of from 12′ to 13′ diameter, with 50 to 55° angle, are preferred on stock lines from 16′ to 17′. The steeper angle helps to prevent ore accumulating on their surface, which injures the distribution. In some cases we obtain just as good if not better results with a 9′ 6″, 50° to 55° angle bell, and an 11′ 6″ Killeen distributor. These sizes are subject to slight variation on different classes of raw materials, and it is often necessary to try them out to find which arrangement suits furnace conditions the best, depending on the ability of the furnace to keep itself clean and work regularly. Also the size and length of the tuyeres best suited to the conditions must be determined.

Distributors, receiving hoppers, and furnace tops are of many types, all of which endeavor to perfect the distribution of stock entering the furnace stack, and either eliminate or compensate for as many irregularities as possible. It is always important to get the stock distributed around the circumference of the large bell as evenly as possible before dumping into the furnace, taking into consideration not only the quantity of materials, but the proportion of coarse and fine. The simplest furnace top that will give good results is always the best, as too much mechanism to look after on the top of a blast furnace is objectionable.

Shape and Position of Off-Takes and Explosion Doors.

Vertical up-takes are taken off the furnace shell as high above the stock line as possible, preferably at four points equally spaced on the circumference. Safety explosion doors to allow relief on slips, but which do not allow large material to be thrown out of the furnace, should be placed on top of the up-takes. Downcomer connections are taken off part way up on up-takes in order to reduce flue dust and return as much material as possible to the furnace on slips. It is important to have these gas openings of sufficient area, so as to reduce the velocity and prevent too much back pressure on the furnace. These off-takes are usually arranged so as not to be directly over the tapping hole, cinder notch, or the entrance of the blast main to the bustle pipe, as a furnace is always more active at these points. This helps to prevent channelling and gives a more even distribution of the gases in their ascent through the stock in the furnace.

Modern Methods of Plugging Tapping Hole and Botting Cinder Notch.

In 1911 it was proposed to plug the tapping hole with the blast on the furnace, and a clay gun for this purpose was described in the *Iron Age* of November 21, 1912. The Carnegie Steel Company was the first to successfully apply a modified form of this gun to plug the tapping hole, and at present it is being used on several of their furnaces. The gun is swung into position mechanically, so that no men are necessary near the tapping hole until the hole receives its first barrel of clay from the gun, which is usually all that is required to plug it. Then, if found necessary, the gun can be operated by a man in the same manner in which the Vaughn gun is operated until sufficient clay has been put into the hole.

The advantages gained by this method are: (1) Safety. (2) More regular working of the furnace, due to the fact that the stock in the bosh does not settle and pack to the

same extent as when the blast is taken off. (3) Increased production. (4) When tuyeres are working wet after casts, the hole can be plugged without cinder running back and filling the blow pipe.

The same company is also using a modern cinder notch botter on some of its furnaces, which consists of a botting bar suspended directly over the cinder notch, arranged to move in a guide in a vertical plane, so that it can be operated by a man standing off to one side of the cinder notch. By this means the danger of a man being burned with splashing cinder, as is the case in the old method of botting with a straight bar, which required a man to stand directly in front of the notch to do the botting, is eliminated.

Considerable savings are made in arrangements of cast houses and the use of large iron ladles, to reduce scrap; also, savings are made in the use of air dump cinder ladles. But, when possible, the commercializing of the slag should be the aim. Further economies are effected by the use of modern machinery for unloading miscellaneous materials, such as coke dust, loam, clay, etc., around the blast furnaces.

These important points have merely been briefly mentioned, as each one in itself is a very important study, and of great interest to a blast furnace manager.

Development of Furnace Lines, Stack Cooling, Etc.

A great amount of thought and study has been given by the Carnegie Steel Company to the lines of blast furnaces since the early days of the Edgar Thomson Furnaces. This plant was one of the pioneers in advancement in this direction, having in consideration the design of lines as affected by the degree of hot blast, materials of burden, and slag composition; effect of lines of a furnace on life of lining, uniformity of product, freedom from high pressures, scaffolding and hanging; and interdependence on each other of lines of furnace, size of bells, tuyeres, blast pressure, amount of wind blown, etc.

Mr. Brassert, at the meeting of the American Iron and Steel Institute, May 22, 1914, read a very valuable paper in which the history of the development of the Edgar Thomson Furnace lines was given; but in his

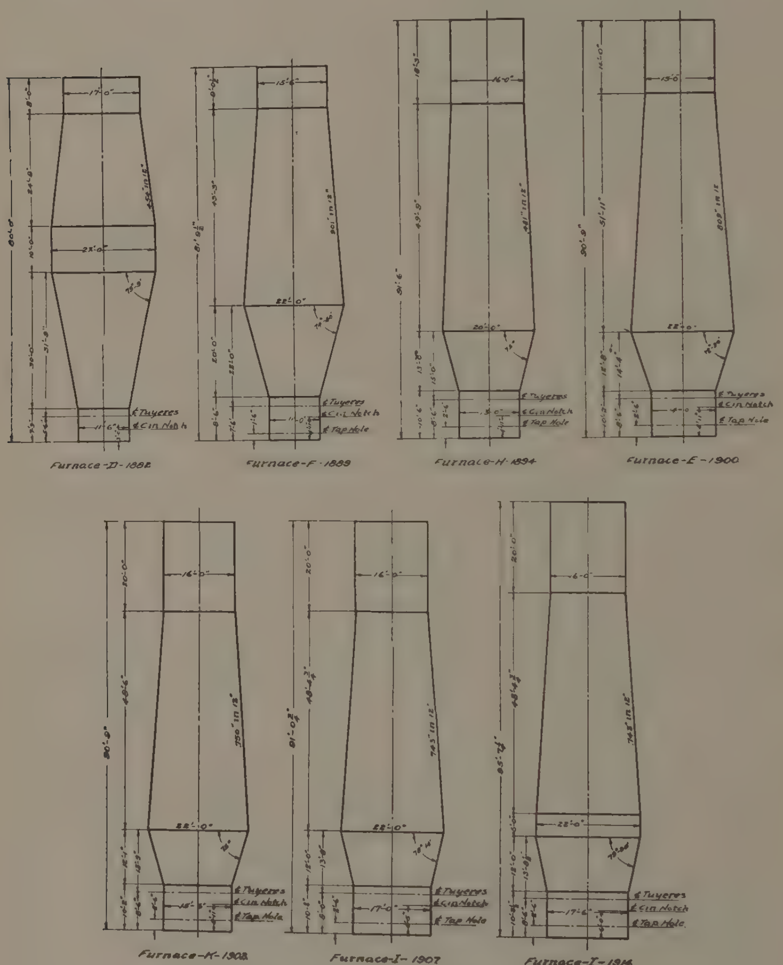


FIG. 1.—Development of Furnace Lines. Edgar Thomson Furnaces. Carnegie Steel Co.

paper he stops at Edgar Thomson Furnace "K", 1902. I have here a similar drawing (see Fig. 1) giving the development up to the present time of the lines of the

Edgar Thomson Furnaces. It will be seen that Furnace "I", having a 17′ hearth, 78° 14′ bosh angle, 16′ stock line, and 22′ bosh, was started in March, 1907. With this furnace we demonstrated that a steep bosh brought about more uniformity in the descent of the charge to the hearth, and we also demonstrated that the short bosh reduced the tendency to hanging. In March, 1908, Mr. Brassert followed with South Chicago Furnace No. 7, with the 17′ hearth and 78° angle.

Furnace "I" has had a very remarkable career on her last lining. It was our first Bessemer or basic furnace, with a partially protected inwall. She was blown out April, 1914, on account of the depressed condition of the iron market at that time, having produced 1,200,000 tons. Fig. 2 shows the lines of Furnace "I"; also the arrangement of stack cooling plates used.

Fig. 1 gives a view of the new proposed lines for Furnace "I", with a 17′ 6″ hearth, 22′ bosh, 79° 20′ bosh angle, 95′ height, and 16′ stock line. We expect to obtain a slightly improved coke consumption from this increase of five feet in height, as the data we have from other furnaces of this height seems to indicate that it will be a slight advantage under our conditions.

BALANCE SHEET OF A BLAST FURNACE.

Heat.—The principal objects in the use of fuel in a blast furnace being the production of heat and the reduction of the ores, from a blast furnace standpoint all successful practice depends on the use of heat in the most scientific and efficient manner. It should be treated as a measurable quantity and mathematically like any other measurable quantity, for although it is not a substance it is one of the most important forms of energy.

Of this energy modern furnace practice attempts to make use of the maximum amount available for producing useful work, and though energy itself is indestructible, the available part is liable to diminution by the action of certain natural processes, such as conduction,

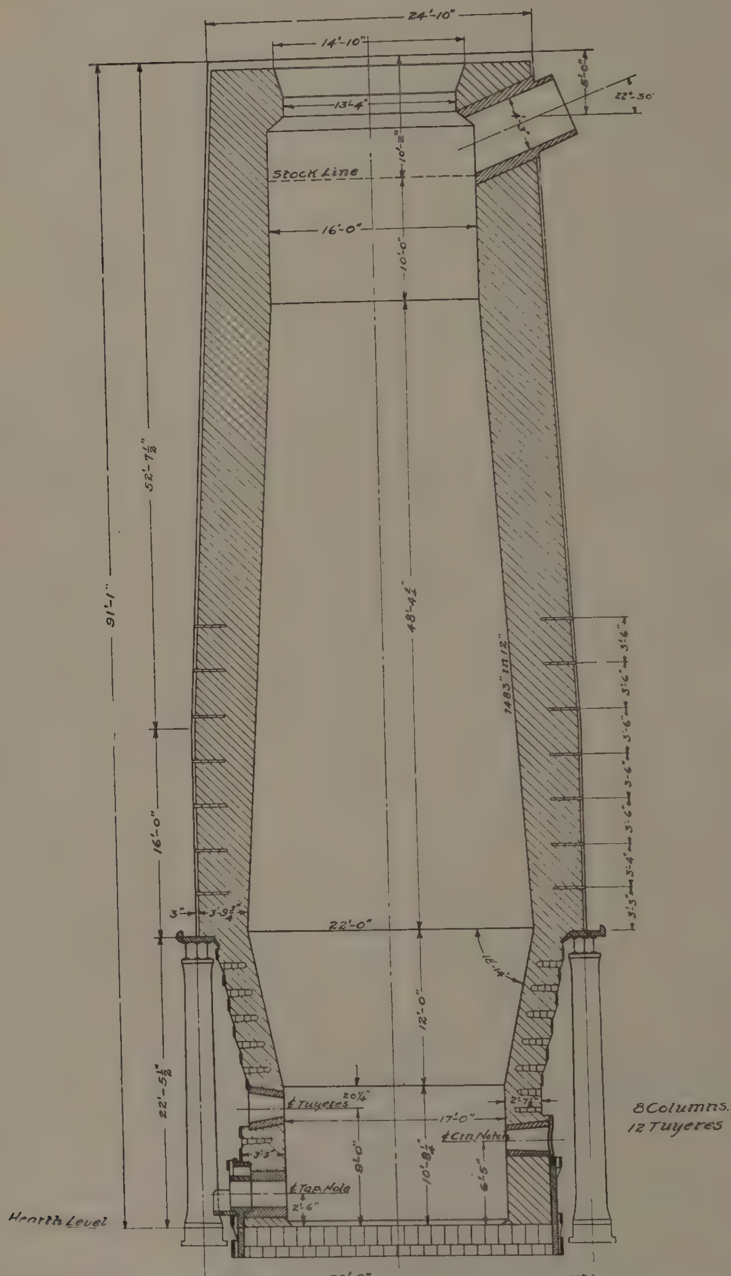


FIG. 2.—Furnace "I" Third Lining. Edgar Thomson Furnaces. Carnegie Steel Co.

radiation, friction, etc. The processes by which energy is rendered unavailable as a source of work are classed together under the name of dissipation of energy, and it is through better understanding of the laws governing this that further improvement and savings in our furnace practice can be obtained.

The Fahrenheit Scale and the British Thermal Unit have been used because they are more familiar in this country. This scale is fixed more forcibly in the minds of our furnace operators on account of being in everyday use.

Before starting on the balance sheet I review below some of the important laws of heat, so that they may be freshened in the memory. This will enable us to more thoroughly understand the balance sheets that follow.

Heat of Combustion.—The heat of combustion of a substance is the quantity of heat given off when a given weight of the substance combines with oxygen, and it is the same whether the union takes place slowly or rapidly. The heat involved in any given chemical reaction is always the same. Chemical action is always accompanied by an evolution or absorption of heat.

Heat of Decomposition.—Just as it is true that a definite quantity of heat is evolved when two or more elements combine chemically, so also it is true that in order to overcome the force which holds these elements together the same quantity of heat must be supplied from some external source, or in the latter case be absorbed.

Chemical Energy and Chemical Work.—Any substance which has the power to unite with others can do chemical work, and it possesses chemical energy.

Details of Balance Sheet Based on Test of a Blast Furnace Using Dry Blast.*

In this test the principal aim was to arrive at the quantity and heat value, by measurement of the blast

*Summary of a test conducted on Isabella Furnace No. 3 of the Carnegie Steel Company, August 5 to 13, 1909.

furnace gases corresponding to the coke consumption of this furnace and to compare the results obtained with a theoretical heat balance sheet as usually calculated.

The results all the way through were fairly satisfactory, and as accurate as could be obtained under the circumstances. The furnace, under other conditions, might have been on lower coke consumption. But the period of test was during the hottest weather of the summer, and it will also be noticed from the burden that cinder volume was rather high, due to the ores used.

A description of the plant is omitted, but Fig. 3 shows the furnace lines, etc., and the various positions at which testing apparatus was attached. This gives sufficient information on these points in a condensed form.

For the first few days of the test some difficulty was experienced in getting correct calorimeter results. These were taken as nearly continuously as possible. The samples of gas for analysis and for calorimeter were taken from the same outlet.

There was difficulty at first through inability to burn this low fuel-value gas in a satisfactory manner, but finally, by improving the burner and adding a larger gasometer, very consistent results were obtained, but they were uniformly lower than the heat value calculated from gas analyses. Some of the reasons for this difference will be noted in the chemical analyses section of this test.

In general the results all the way through are as accurate and consistent as it is possible to obtain in a test of this kind. Every precaution was taken to calibrate instruments accurately, also to check all scales, etc., on which the materials were weighed.

The complete results obtained during the test are tabulated in detail, together with the general averages of all the results obtained. For simplicity, the test is divided into the following sections:

(1) Burden and Products.

(2) Chemical Results.

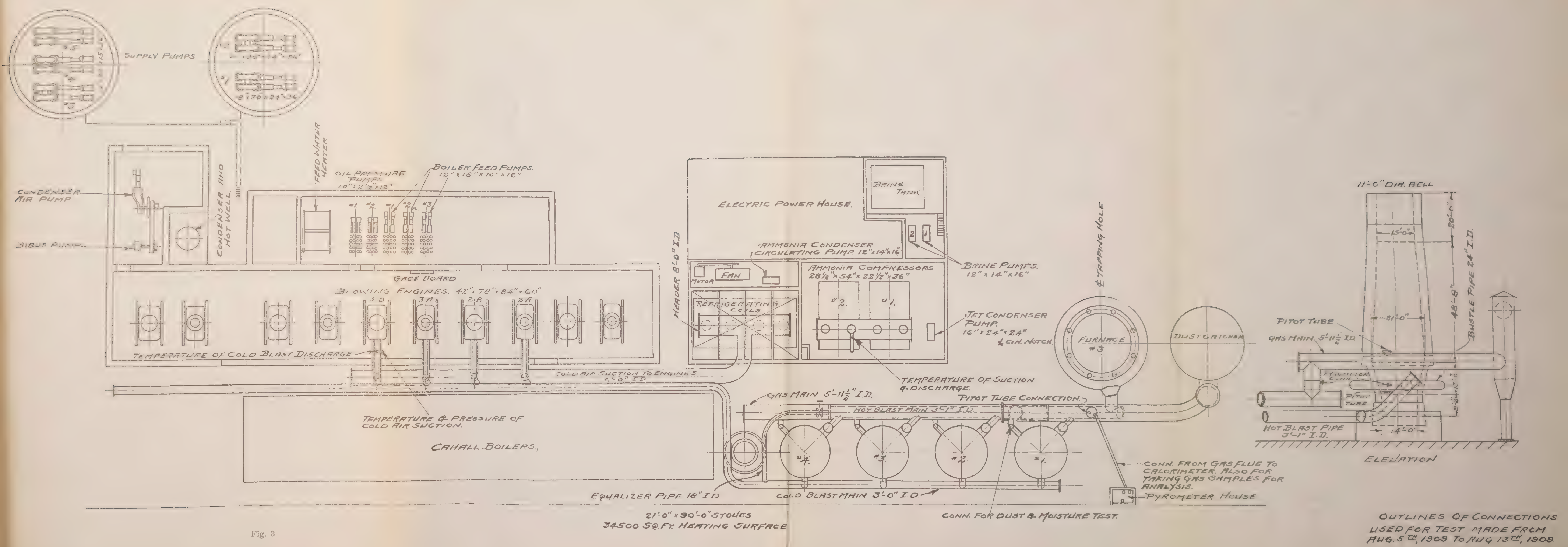

SUPPLY PUMPS
CONDENSER AIR PUMP
BIBUS PUMP
CONDENSER AND HOT WELL
FEED WATER HEATER
OIL PRESSURE PUMPS 10" x 2 1/2" x 12"
BOILER FEED PUMPS. 12" x 18" x 10" x 16"
GAGE BOARD
BLOWING ENGINES. 42" x 78" x 84" x 60"
3 B
3 A
2 B
2 A
TEMPERATURE OF COLD BLAST DISCHARGE
COLD AIR SUCTION TO ENGINES. 6'-0" I.D.
TEMPERATURE & PRESSURE OF COLD AIR SUCTION.
CAHALL BOILERS.
ELECTRIC POWER HOUSE.
BRINE TANK
AMMONIA CONDENSER CIRCULATING PUMP 12" x 14" x 16"
FAN
MOTOR
REFRIGERATING COILS
HEADER 8'-0" I.D.
AMMONIA COMPRESSORS 28 1/2" x 54" x 22 1/2" x 36"
#2.
#1.
BRINE PUMPS. 12" x 14" x 16"
JET CONDENSER PUMP. 16" x 24" x 24" & CIN. NOTCH.
TEMPERATURE OF SUCTION & DISCHARGE.
℄ TAPPING HOLE
FURNACE #3
DUSTCATCHER
PITOT TUBE CONNECTION.
GAS MAIN. 5'-11 1/2" I.D.
HOT BLAST MAIN 3'-1" I.D.
#4.
#3.
#2.
#1.
EQUALIZER PIPE 18" I.D
COLD BLAST MAIN 3'-0" I.D.
21'-0" x 90'-0" STOVES
34500 SQ. FT. HEATING SURFACE
CONN. FOR DUST & MOISTURE TEST.
CONN. FROM GAS FLUE TO CALORIMETER. ALSO FOR TAKING GAS SAMPLES FOR ANALYSIS.
PYROMETER HOUSE
11'-0" DIA. BELL
20'-0"
15'-0"
48'-8"
21'-0"
BUSTLE PIPE 24" I.D.
PITOT TUBE
GAS MAIN. 5'-11 1/2" I.D.
PYROMETER CONN.
PITOT TUBE
HOT BLAST PIPE 3'-1" I.D.
14'-0"
ELEVATION.
OUTLINES OF CONNECTIONS USED FOR TEST MADE FROM AUG. 5TH, 1909 TO AUG. 13TH, 1909.

Fig. 3

(3) Gas, Air, and Power Measurements.
(4) Theoretical Heat Balance.*
(5) General Summary and Comparisons.

BURDEN AND PRODUCTS.

	Pounds.	Pounds per Ton of Iron Produced.
Total ore charged	14,392,600	4,435.3
Total coke charged	6,253,400	1,927.1
Total coke dust left in cars	25,900	
Total coke charged to furnace	6,279,300	
Total stone used	4,859,920	1,497.6
Total flue dust produced	656,900	202.4
Total scrap used	420,700	
Total scrap produced	317,500	
Scrap difference	103,200	
Total product	3,245 tons (2,240 pounds)	

NOTE.—Although the scrap used is in excess of the scrap produced, it is so small that the actual product will be taken as 3,245 tons.

No flue dust was used.

Weights given are totals of car-load lots of materials used, all scales being checked.

Cinder Produced.—On account of the cinder from the furnaces being handled by a cinder machine, it was watered and loaded into cars wet. It was consequently necessary to obtain samples that would furnish a good basis for the calculation of moisture, due to the fact of the difference in the quality of cinder and the length of time cars stood before being weighed. However, in sampling, the wettest portions obtained by digging down in tops of cars were taken, and they are probably nearly representative.

An average of these daily samples showed 13.57 per cent. moisture.

*The arrangement of Heat Balance is somewhat similar to arrangement given by Professor Joseph W. Richards in his interesting book on "Metallurgical Calculations."

BURDEN—BASED ON TOTAL MATERIALS CHARGED.

	Total Materials Pounds	Silica Per Cent.	Silica Pounds	Alumina Per Cent.	Alumina Pounds	CaO and MgO Per Cent.	CaO and MgO Pounds	Iron Per Cent.	Iron Pounds	Phosphorus Per Cent.	Phosphorus Pounds	Manganese Per Cent.	Manganese Pounds
Ore:													
Mesaba	8,929,600	5.73	511,666	3.61	322,359	.47	41,969	48.48	4,329,070	.070	6,250.72	.76	67,864.96
Old Range.........	5,463,000	11.12	607,486	2.48	135,482	1.17	63,917	51.52	2,814,538	.052	2,840.76	.18	9,833.40
Total	14,392,600		1,119,152										
Coke	6,253,400	6.98	436,487	3.88	242,633	.19	11,881	1.09	68,162	.013	812.94	.03	1,876.02
Limestone	4,859,920	6.63	322,213	2.72	132,190	49.58	2,409,548	.21	10,206	.013	631.79		
Total			1,877,852		832,664		2,527,315		7,221,976		10,536.21		79,574.38
Deduct flue dust....	656,900	7.92	52,026	4.10	26,933	1.78	11,692	51.23	336,530	.083	545.23	.46	3,021.74
Net Total........			1,825,826		805,731		2,515,623	93.20	6,885,446		9,990.98		76,552.64
Less 1 per cent. Si. in Metal.........			158,099					100.00	7,387,817				1/6 loss=12,758.77
									3,298 tons				
Totals		32.36	1,667,727	15.63	805,731	48.81	2,515,623			.135	9,990.98	.86	63,793.87

Total cinder volume = 5,154,009 pounds. Pounds cinder per ton of metal = 1,561 pounds.

Analyses of slag show the $FeO + MnO_2 + S = 3.2$ per cent., so have taken the SiO_2 and $CaO + MgO$ as furnishing 96.8 per cent. of the total slag produced. Analyses of iron show Total Carbon + Mn + P + S + Si = 6.8 per cent., so have taken the Total Fe in burden as 93.2 per cent. of total iron produced. Taking into account losses of flue dust in stoves, boilers and stacks, which could not be weighed, together with Fe going into the slag, the calculated product checks very closely with the actual.

DAILY STOCK SHEET.

	For 24 hours ending at 9.00 A. M. on Aug. 6	Aug. 7	Aug. 8	Aug. 9	Aug. 10	Aug. 11	Aug. 12	Aug. 13	Total for 8 Days of Test
Pounds of ore used:									
Mesaba	1,051,200	1,081,200	1,184,000	1,086,400	1,093,200	1,154,400	1,139,600	1,139,600	8,929,600
Old Range	657,000	666,000	720,000	666,000	666,000	702,000	693,000	693,000	5,463,000
Total	1,708,200	1,747,200	1,904,000	1,752,400	1,759,200	1,856,400	1,832,600	1,832,600	14,392,600
Pounds of scrap used:									
Ladle	14,700	14,700	16,100	11,900	None	1,800	18,200	14,700	
Pig Machine	28,700	28,000	32,900	35,000	43,400	39,700	30,800	33,600	
Runner	7,700	9,100	7,000	4,900	8,400	8,900	4,900	5,600	
Total	51,100	51,800	56,000	51,800	51,800	50,400	53,900	53,900	420,700
Pounds of stone used	578,160	586,080	633,600	589,600	597,920	630,240	622,160	622,160	4,859,920
Pounds of coke used	752,000	762,300	824,000	762,300	762,300	803,500	793,500	793,500	6,253,400
Tons of iron produced	410.0800	369.0840	446.0960	384.1240	404.0140	407.0220	419.1340	404.1040	3,245.0000
Pound of coke per ton of iron	1,835	2,067	1,849	1,980	1,886	1,975	1,889	1,964	1,927
Tons of flue dust produced	42.1720	None	50.0060	50.2100	54.0540	26.0860	19.2140	48.1580	293.0000

Car weights on cinder show the total produced to be.....	5,895,200 pounds
Less 13½ per cent. moisture..........................	795,852 pounds
Net weight of cinder..................................	5,099,348 pounds

This checks very closely with the figure 5,154,009 given in burden.

Chemical Results.

Analyses Obtained.

(1) The different grades of ore, stone and coke used by the furnace were sampled four times in each 24 hours, and complete analysis made each day of the combined sample, and averaged at completion of test.

(2) Iron produced and cinders were sampled on each cast or flush of the furnace and analyzed.

(3) Gas analyses are referred to elsewhere.

(4) Average flue dust analysis was taken from average samples collected daily during the test.

(5) The scrap analysis was estimated.

ANALYSES OF IRON PRODUCED.

For 24 Hours Ending at 9.00 A. M. on 1909	Iron	Silicon	Sulphur	Phos.	Mang.	Total Carbon
August 6.........	93.15	1.14	.034	.160	.82	4.70
August 7.........	93.20	1.00	.032	.162	.86	4.75
August 8.........	93.58	1.00	.037	.152	.70	4.53
August 9.........	93.61	1.10	.044	.148	.70	4.40
August 10.........	92.91	1.32	.028	.150	.92	4.67
August 11.........	93.00	.83	.025	.152	1.10	4.89
August 12.........	92.88	1.00	.023	.156	1.00	4.94
August 13.........	93.27	.82	.028	.150	.98	4.75
Average	93.20	1.03	.031	.154	.89	4.70
Adjusted...........	93.20	1.03	.030	.150	.89	4.70

AVERAGES OF HOURLY GAS ANALYSES BY VOLUME.

(Dry Gas, at 62° F. and 30″ Hg.)

Date	CO_2	CO	H_2	CH_4	N_2	Total	B. T. U. Calculated	B. T. U. Calorimeter Wet Gas	B. T. U. Calorimeter Dry Gas	Moisture Grains per Cu. Ft. Dry Gas as Metered
August 5.........	15.59	23.35	1.70	.086	59.05	99.776	82.86	.....	.....	25.75
August 6.........	16.30	22.06	1.31	.046	60.24	99.956	76.09	.....	.....	19.58
August 7.........	15.87	22.92	1.88	.063	59.25	99.983	81.09	74.63	76.04	15.08
August 8.........	16.59	22.97	2.18	.040	58.17	99.910	81.86	76.96	78.41	22.23
August 9.........	16.52	22.31	2.15	.013	59.00	99.993	79.33	75.50	76.92	21.63
August 10.........	16.65	22.62	2.16	.023	58.55	100.003	80.56	75.80	77.23	17.58
August 11.........	16.45	22.71	1.98	.017	58.50	100.007	79.99	76.00	77.43	18.26
August 12.........	16.57	22.78	2.53	.004	58.10	100.004	82.23	76.24	77.68	19.65
Average	16.32	22.715	1.99	.0365	58.86	99.9215	80.55	75.84	77.27	19.97
Adjusted	16.33	22.73	1.99	.04	58.91	100.000	.....	.....	.....	20.05 average of all readings during test.

Results of Calorimeter Tests and Moisture Determinations of Furnace Gas.

Analyses were made hourly with but few results lost through accident to apparatus. The calorimeter results were not entirely satisfactory, the results for the first two days being discarded entirely, as the gas would not burn properly in the ordinary burner owing to its leanness and to slight pulsations in the main. We were able to keep the gas burning by devising an inverted burner which permitted a slight preheating and kept the jet burning toward the flow of gas. The pulsations were taken care of by placing a gasometer, relatively large with reference to the amount of gas burned, in the line. Moisture results were not obtained regularly during the first part of the test owing to all the attention being given the calorimeter.

The Technologic Branch of the United States Geological Survey, Pittsburgh, stated that with a lean gas, around 80 B.T.U., they also had been unable to get satisfactory results, and had to depend on the B.T.U. results calculated from the analyses in such cases.

The methods used for gas analysis were the accepted methods in general use, as follows:

Carbon dioxide: absorption by caustic potash.

Oxygen: absorption by pyrogallic acid.

Carbon monoxide: absorption by ammoniacal cuprous chloride.

Hydrogen and methane: the residue was enriched with hydrogen and exploded.

While a more expeditious method is available, that used is in wider general use, and as previous analyses of gas from dry blast furnaces have had the carbon monoxide determined by cuprous chloride, it was thought best to adhere to that method.

SUMMARY OF CHEMICAL RESULTS OF TEST

Average Iron Analysis

Iron	Silicon	Sulphur	Phosphorus	Manganese	Total Carbon
93.20	1.03	.030	.150	.89	4.70

Average Ore Analyses

	SiO_2	Fe_2O_3	Fe	MnO_2	Mn	P_2O_5	P.	Al_2O_3	CaO	MgO	Loss on Ignition	Moisture
Mesaba	5.73	69.26	48.48	1.21	.76	.16	.070	3.61	.25	.22	5.17	14.39
Old Range........	11.12	73.60	51.52	.28	.18	.12	.052	2.48	.78	.39	2.47	8.76

Average Coke Analysis

SiO_2	Al_2O_3	CaO	MgO	FeS	MnO_2	Mn	P_2O_5	P.	Fixed Carbon	Volatile Matter	Moisture
6.98	3.88	.12	.07	1.72	.05	.03	.03	.013	83.27	1.02	2.86

Average Limestone Analysis

SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	P.	CaO	MgO	CO_2	FeS	Moisture
6.63	2.72	.30	.030	.013	47.53	2.05	39.53	.21	1.00

Average Flue Dust Analysis

SiO_2	Al_2O_3	CaO	MgO	MnO_2	Mn	P_2O_5	P.	Fe_2O_3	Fe	Fixed Carbon	CO_2	Moisture
7.92	4.10	1.45	.33	.72	.46	.19	.083	73.18	51.23	10.51	.90	.70

Average Slag Analysis

SiO_2	CaO	MgO	CaS	S.	Al_2O_3	FeO	MnO_2
33.74	43.24	3.82	2.41	1.07	14.64	1.42	.73

Gas, Air and Power Measurements.

Dry Blast Delivered by Engines.

Pressure entering engines = 1.29″ H_2O.
Temperature entering engines = 51.6° F.
Total revolutions = 979,691.
Diameter blowing cylinder = 84″.
Diameter piston rod = 7½″.
Stroke of engines = 60″.
Cu. ft. piston displacement per revolution = 381.7.
Total gross wind delivered = 373,948,055 cu. ft.
Corrected to 62° F. and 30″ Hg. pressure = 375,647,275 cu. ft. (wet).
Average corrected blast = 32,608 cu. ft. (wet) per minute of total running time.

Air Passed Through Hot Blast Main as Shown by Pitot Tube.

Blast pressure = 15.04 lbs.
Blast temperature = 833.4° F.
Average reading of Pitot tubes = 1.252″ H_2O.
Diameter of main = 3 ft. 1 in. = 7.467 sq. ft.
Density of hot blast = .0615 wet.
Gross cu. ft. hot blast per hour = 2,218,134, wet.
Total gross cu. ft. = 425,881,728, wet.

Periodic losses to be deducted:

57 Stoves at 8,987.63 cu. ft.	512,295 cu. ft
40 Casts aggregating 93 minutes that snorter valve was open and one engine made 12 R.P.M., including 13 minutes for changing monkey	529,000 cu. ft.
49 Checks including casts when engines were operating under reduced revolutions and counted equal losses by snorter valve	567,473 cu. ft.
Total loss	1,608,768 cu. ft.

Actual hot blast entering furnace = 425,881,728 — 1,608,768 = 424,272,960 cu. ft., wet.
Corrected to 62° F. and 30″ Hg. pressure = 342,979,715 cu. ft., wet.
Net hot blast at 62° F. and 30″ Hg. entering furnace per minute of net operating time = 30,015 cu. ft., wet.
Entire loss from engine to tuyeres = 375,647,275 — 342,979,715 = 32,667,560 cu. ft. = 8.70%.
N_2 in air (dry) = 79.2%.
N_2 in air (dry) as blown = 78.85%.
N_2 in gas (dry) = 58.91%.
Ratio = 1.3383
342,979,715 × 1.3383 = 459,009,753 cu. ft. gas (dry).
Tons metal produced = 3,245.
Corrected gas per ton = 141,451 (dry).

Actual Gas Leaving Furnace as Measured by Pitot Tube in Gas Main.

Gas pressure = 5.32″ H_2O.
Gas temperature = 324° F.
Average reading of Pitot tubes = 0.208″ H_2O.
Diameter of main = 71½″ = 27.88 sq. ft. area.
Density of gas = .051329, wet.
Density of gas = .052532, dry.
Specific gravity = 1.017, wet.
Specific gravity = 1.041, dry.
Gas per hour = 3,695,048 cu. ft., wet.
Total for 8 days (less 93 minutes) = 703,721,892 cu. ft., wet.
Total for 8 days (less 93 minutes) = 663,661,116 cu. ft., dry.
Corrected to 62° F. and 30″ Hg. pressure = 439,173,098 standard gas, dry.
Metal produced = 3,245 tons.
Corrected gas per ton iron = 135,338 cu. ft. standard gas, dry.*

*This would probably be reduced slightly by the dirt that had collected in gas flue, which amounts we were unable to obtain.

INDICATED HORSEPOWER AND BOILER HORSEPOWER REQUIRED.

Engines, pumps, etc.	I.H.P.	Total H.P. Hours During Test	Total KW. Hours During Test	H.P. to Furnace No. 3	Total Hours to Furnace H. P. No. 3	Steam Per Hour Per I.H.P. Lbs.	Equivalent Total Boiler H.P. Hours to Furnace No. 3	Number and Dimensions of Units (All Pumps Duplex Except)	
Blowing engines	1,758.64	337,658.9	....	1,758.64	337,658.9	20	205,264	2 Todd Independent Comp. Cond. & 1 High Press. Cond.	42×78×84×60″
NH_3 compressors	499.15	95,836.8	....	499.15	95,836.8	21	61,172	2 York Mfg. Co. Cross Comp. Cond.	28½×54×22½×36″
Supply pump No. 1	84.32	16,189.4		104.27	20,020.3	80	48,680	1 W. & Snyder Comp. Non-Cond.	18×30×24×36″
Supply pump No. 2	112.32	21,565.4						1 E. & Carpenter Comp. Non-Cond.	21×36×24×36″
Supply pump No. 3	3.86	741.1						3 W. & Snyder Comp. Non-Cond.	12×22×15×36″
Supply pump No. 4	47.94	9,204.5							
Supply pump No. 5	49.48	9,500.2							
Boiler feed pump No. 1	16.01	3,703.9		13.06	2,717.5	80	6,608	3 E. & Carpenter Comp. Non-Cond.	12×18×10×16″
Boiler feed pump No. 2	8.17	1,568.6							
Boiler feed pump No. 3	15.00	2,880.0							
Brine pump	14.11	2,709.1	....	14.11	2,709.1	100	8,234	1 E. & Carpenter Simple Non-Cond.	12×14×16″
NH_3 condensing circ. pump	14.17	2,720.6	....	14.17	2,720.6	100	8,239	1 E. & Carpenter Simple Non-Cond.	12×14×16″
Comp.-room condensing pump	7.67	1,472.6	....	7.67	1,472.6	100	4,476	1 E. & Carpenter Simple Non-Cond.	16×24×24″
Blowing-room cond. eng	57.26	10,993.9	....	19.08	3,664.6	33	3,664	1 Weiss Condenser Simple Eng.	16×22×24″
Cinder casting mch. eng	50.00	2,000.0	....	50.00	2,000.0	35	2,128		
Charging furnace-skips, Larry	....	....	763.3	....	1,206.0	23	843		
Fan motor	....	....	5,455.0	....	8,618.9	23	6,025		
Pig machine motor	....	....	1,238.8	....	1,957.3	23	1,368		
					480,582.6 = 2,503 I. H. P.		356,701 = 1,858	Boiler H. P. Net.	

One Boiler H. P. Hour = 32.9 lbs. water.
Water rating of blowing engines and compressors taken from indicator cards; other ratings assumed.
Distribution of power: 35% of supply pumps; 33 1/3% of boiler feed pumps; 33 1/3% of blowing engine room condenser engine.

AVERAGES OF DATA.

		August 5th	August 6th	August 7th	August 8th	August 9th	August 10th	August 11th	August 12th	Avg. for 192 Hrs.
PRESSURES.										
1. Barometer	In. Hg.	29.312	29.452	29.537	29.470	29.400	29.500	29.480	29.360	29.440
2. Air in refrigerating rooms	In. H_2O.	2.110	2.500	2.420	2.630	2.500	2.510	2.458	2.620	2.470
3. Air entering blowing engines	In. H_2O.	1.313	1.231	1.850	0.990	1.167	1.250	1.246	1.784	1.290
4. Air leaving blowing engines	Lbs., Sq. In.	15.490	13.390	14.820	15.910	14.990	15.910	15.720	15.230	15.040
5. Air at blast furnace tuyeres	Lbs., Sq. In.	15.110	13.310	15.090	16.400	15.300	15.340	15.230	15.570	15.120
6. Difference of pressure by Pitot tubes (hot blast)	In. H_2O.	1.234	1.310	1.257	1.182	1.201	1.283	1.297	1.248	1.252
7. Difference of pressure by Pitot tubes (gas main)	In. H_2O.	.220	.185	.187	.206	.212	.203	.227	.225	.208
8. Gas in main	In. H_2O.	3.79	4.26	4.72	5.07	6.55	5.80	5.95	6.25	5.32
9. Steam in blowing-room	Lbs., Sq. In.	115.2	115.6	115.6	116.8	116.9	116.4	115.7	116.4	116.1
10. Steam in NH_3 compressor-room	Lbs., Sq. In.	114.9	117.6	116.7	117.1	116.5	117.3	116.9	117.5	116.8
11. Vacuum in blowing-rooms	In. Hg.	25.54	25.58	26.01	26.07	26.04	26.11	26.00	25.67	25.88
12. Vacuum in NH_3 compressor-room	In. Hg.	19.96	20.49	19.84	20.06	19.73	20.67	20.73	20.13	20.20
13. Water at main supply pumps—suction	In. Hg.	....	....	6.50	6.56	6.38	6.25	6.42	6.12	6.15
14. Water at main supply pumps—outlet	Lbs., Sq. In.	65.5	65.3	65.3	65.5	65.7	66.0	66.1	65.4	65.7
15. Water at boiler feed pumps—outlet	Lbs., Sq. In.	148.3	147.2	147.6	147.6	147.8	149.2	149.2	149.4	148.3
16. Water at NH_3 condenser circulating pumps—inlet	Lbs., Sq. In.			Measured from Drawing						2.2
17. Water at NH_3 condenser circulating pumps—outlet	Lbs., Sq. In.			Measured from Drawing						28.3
18. Oil in lines to furnace bells	Lbs., Sq. In.	941.0	946.9	947.5	941.3	942.0	940.8	944.6	938.8	941.6
19. Brine circulating pumps—inlet	Lbs., Sq. In.			Measured from Drawing						2.0
20. Brine circulating pumps—outlet	Lbs., Sq. In.	31.3	30.6	31.4	31.2	31.3	31.3	31.4	31.4	31.2
21. NH_3 compressors—head	Lbs., Sq. In.	195.3	193.1	195.4	195.5	196.5	186.5	185.7	189.1	192.1
22. NH_3 compressors—back	Lbs., Sq. In.	14.3	14.5	15.5	15.5	16.5	13.5	13.2	14.5	14.7
TEMPERATURES.										
23. Air entering refrigerating-room	Degrees F.	78.0	81.3	82.1	84.0	85.8	77.5	77.5	75.4	80.2
24. Air leaving refrigerating-room	Degrees F.	34.7	38.0	37.9	36.9	37.8	34.0	32.9	36.4	36.1
25. Air entering blowing engine	Degrees F.	49.4	52.0	52.8	55.4	54.2	48.4	49.3	49.4	51.6
26. Air leaving blowing engine	Degrees F.	169.3	158.3	164.9	175.7	167.6	165.2	167.8	169.4	167.2
27. Hot blast entering tuyeres	Degrees F.	857.0	706.2	857.9	985.2	812.5	794.2	800.4	853.2	833.4
28. Gas leaving blast furnace	Degrees F.	....	....	416.9	357.9	300.2	276.0	304.0	312.8	324.0
29. Gas at B. & W. Boilers (No. 3 Furnace)	Degrees F.	327.7	298.2	333.3	314.9	271.7	263.4	277.3	288.7	291.8
30. Water in supply mains	Degrees F.	76.3	75.9	77.2	77.1	76.9	75.7	76.3	75.5	76.4
31. Water leaving blast furnace	Degrees F.	79.0	81.6	82.4	83.4	82.0	81.3	81.4	81.2	81.5
32. Water in hot well at blowing-room	Degrees F.	129.6	126.5	125.8	128.8	128.3	129.6	133.9	129.3	129.4
33. Water leaving condenser pump in compressor-room	Degrees F.	134.4	133.9	132.5	132.7	135.2	128.3	127.2	129.5	131.3
34. Water leaving feed water heater	Degrees F.	179.3	175.4	174.0	174.7	181.3	180.8	178.8	180.5	177.6
35. Water on NH_3 condenser coils	Degrees F.	76.3	75.9	77.25	77.13	76.9	75.7	76.3	75.5	76.3
36. Water leaving NH_3 condenser coils	Degrees F.	85.9	85.6	86.75	87.04	88.3	84.4	84.2	85.1	85.9

AVERAGES OF DATA.

		August 5th	August 6th	August 7th	August 8th	August 9th	August 10th	August 11th	August 12th	Totals for 192 Hrs.	Avg. for 192 Hrs.
37. Brine in feed lines	Deg. F.	12.4	13.1	13.9	14.08	16.3	11.0	12.9	12.2	....	13.2
38. Brine in return lines	Deg. F.	22.3	23.3	23.9	24.20	26.7	19.9	21.0	21.2	....	22.8
39. NH_3 entering compressors	Deg. F.	......	....	....	.....	....	20.83	28.0	25.2	....	24.5
40. NH_3 leaving compressors	Deg. F.	......	....	....	.....	....	278.3	280.9	270.0	....	276.1
REVOLUTIONS OF ENGINES AND COMPRESSORS.		(a)							(b)		
41. Total revolutions of blowing engines	Rev.	117,346	123,299	123,465	117,842	122,917	123,033	123,808	127,981	979,691	......
42. Average R. P. M.	R.P.M.	84.3	85.6	85.7	81.9	85.4	85.4	85.9	83.3	....	84.96
43. Total R. P. M. of NH_3 compressors (2)	R.P.M.	100	100	100	100	100	97	90	100	....	97.8
44. R. P. M. of blowing engine-room cond. engine	R.P.M.	77.4	78.8	78.4	78.2	77.8	74.1	77.8	78.4	....	......
DOUBLE STROKES OF PUMPS PER MINUTE.		(a)							(b)		
45. Total D. S. of brine pumps	D. S.	30,043	31,411	31,756	31,609	31,670	31,558	31,332	32,986	252,365	......
46. Average D. S. of brine pumps per minute	D. S.	21.8	21.8	22.0	21.9	21.9	21.9	21.7	21.9	....	21.9
47. Total D. S. NH_3 condenser circulating pump	D. S.	(a) 362	489	490	506	489.5	510	496.5	(b) 532	237,450	20.6
48. Total D. S. boiler feed No. 1 and No. 2 pumps	D. S.	(a) 584.5	593.5	570	605.5	570.5	567.5	577.0	(b) 587.5	277,947	24.1
49. Total D. S. condenser pump compressor-room	D. S.	(a) 879	894	879	862	866	871	899	(b) 909	241,344	36.6
50. Total D. S. supply pump No. 1	D. S.	(a) 107	122	93.5	108.5	114	114	115	(b) 112.5	105,281	9.2
51. Total D. S. supply pump No. 2	D. S.	(a) 166	162	133.5	158	161	144.5	130.5	(b) 164.5	144,887	12.6
52. Total D. S. supply pump No. 3, 4 and 5	D. S.	(a) 364	386.5	447	392	386.5	404.5	413.5	(b) 415.5	381,172	33.1
59. Moisture in atmosphere per cu. ft.	Grains	6.173	5.918	5.838	7.000	6.774	4.337	4.262	6.010	....	5.789
60. Moisture in dry blast per cu. ft.	Grains	1.522	1.558	1.555	1.558	1.738	1.488	1.495	1.558	....	1.560
53. Average length of pump strokes (supply)	Inches	......	.....	.....	.....	.....	.....	.....	.....	....	34.2
54. Average length of pump strokes (brine)	Inches	......	.....	.....	.....	.....	.....	.....	.....	....	14.7
55. Average length of pump strokes (NH_3 cond. circ. pump)	Inches	......	.....	.....	.....	.....	.....	.....	.....	....	13.2
56. Average length of pump strokes (compressor-room)	Inches	......	.....	.....	.....	.....	.....	.....	.....	....	20.0
57. Average length of pump strokes (boilers)	Inches	......	.....	.....	.....	.....	.....	.....	.....	....	13.3
58. Average length of pump strokes (oil pressure)	Inches	......	.....	.....	.....	.....	.....	.....	.....	....	11.6

Brine pump and blowing engine revolutions taken with counters.
(a) For 23 hours and have added 1,000 revolutions for time counter was out of commission on Engine 2-A, August 5th.
(b) For 25 hours.

Balance Sheet of Basic Burden.

Average Burden.

14,800 lbs. Mesaba ore.
9,000 lbs. Old Range ore.
700 lbs. Scrap.
10,200 lbs. Coke.
8,080 lbs. Stone.

Total Ores Used.

Mesaba	= 62.04%	= 8,929,600 lbs.
Old Range	= 37.96%	= 5,463,000 lbs.
	100.00%	14,392,600 lbs.

Pounds of Materials Used per Ton of Metal Produced.

Ore = 4,435.3 lbs.
Coke = 1,927.1 lbs.
Stone = 1,497.6 lbs.
Flue dust produced per ton of iron = 202.4 lbs.
Cinder produced per ton of iron = 1,571.45 lbs.
Temperature of blast = 833° F.
Temperature of waste gases = 324° F.
Average composition of waste gases, CO_2 = 16.33%, CO = 22.73%
Product per day, tons (2,240 lbs.) = 405.62 = 3,245 tons total product.

Average Analyses.

IRON		CINDER		FLUE DUST PRODUCED	
Iron	93.20	SiO_2	33.74	SiO_2	7.92
Silicon	1.03	CaO	43.24	Al_2O_3	4.10
Sulphur	.03	MgO	3.82	CaO	1.45
Phos.	.15	CaS	2.41	MgO	.33
Manganese	.89	Al_2O_3	14.64	MnO_2	.72
Total C.	4.70	FeO	1.42	P_2O_5	.19
		MnO	.73	Fe_2O_3	73.18
				Fixed C.	10.51
				CO_2	.90
				Moisture	.70
Total	100.00	Total	100.00	Total	100.00

Correction for Net Coke Used.

Flue dust produced per ton of iron = 202.4 lbs.
Total weight of fixed carbon in flue dust; 202.4 × 10.51% = 21.272 lbs.
Total weight of coke in flue dust; $\frac{21.272}{83.26\%}$ (Fixed carbon in coke) = 25.55 lbs.
Net coke used in furnace per ton of iron; 1,927.1 — 25.55 = 1,901.55 lbs.
Figure used = 1,901.6 lbs.

Correction for Net Stone Used.

Flue dust produced per ton of iron = 202.4 lbs.
Total weight of CO_2 in flue dust produced; 202.4 × 0.9 = 1.82 lbs.
Total weight of limestone in flue dust; $\frac{1.82}{39.53\%}$ (CO_2 in stone) = 4.60 lbs.
Net stone charged in furnace per ton of iron; 1,497.6 — 4.6 = 1,493 lbs.

Correction for Net Ore Used.

Weight of ore charged per ton of metal = 4,435.3 lbs.
Weight of stone in flue dust = 4.6 lbs.
Weight of coke in flue dust = 25.55 lbs.

30.15 lbs.
Weight of ore in flue dust (202.4 — 30.15) = 172.25 lbs.

Net ore used per ton of iron = 4,263.05 lbs.
Figure used = 4,263.00 lbs.

Final Adjustment of Ore Analyses.

	Mesaba		Old Range		Total Ore	
	Per Cent.	Lbs.	Per Cent.	Lbs.	Lbs.	Per Cent.
SiO_2	5.73	511,666	11.12	607,486	1,119,152	7.78
Fe_2O_3	69.26	6,184,642	73.60	4,020,768	10,205,410	70.91
MnO_2	1.21	108,048	.28	15,296	123,344	.85
P_2O_5	.16	14,287	.12	6,556	20,843	.15
Moisture	14.39	1,284,969	8.76	478,559	1,763,528	12.25
Al_2O_3	3.61	322,359	2.48	135,482	457,841	3.18
CaO	.25	22,324	.78	42,611	64,935	.45
MgO	.22	19,645	.39	21,306	40,951	.28
Ign. loss..........	5.17	461,660	2.47	134,936	596,596	4.15
Totals		8,929,600		5,463,000	14,392,600	100.00

BALANCE SHEET OF BASIC BURDEN AND BLAST.

Per ton (2,240 lbs.) of iron produced.

Charges	Per Cent.	Pounds	Pig	Slag	Gases
ORE					
H_2O =	16.40	699.13			H_2O = 699.13
SiO_2 =	7.78	331.66	Si = 23.072	SiO_2 = 282.588	O = 26.00
Al_2O_3 =	3.18	135.56		Al_2O_3 = 135.560	
CaO =	.45	19.18		CaO = 19.180	
MgO =	.28	11.94		MgO = 11.940	
Fe_2O_3 =	70.91	3,022.89	Fe = 2,083.495	Scrap = 32.525	O = 906.870
P_2O_5 =	.15	6.40	P = 2.793		O = 3.607
MnO_2 =	.85	36.24	Mn = 19.936	MnO = 3.840	O = 12.464
	100.00				
Total ore......		4,263.00			
FLUX					
SiO_2 =	6.63	98.98		SiO_2 = 98.98	
Al_2O_3 =	2.72	40.61		Al_2O_3 = 40.61	
P_2O_5 =	.03	.45	P = .19		O = .26
CaO =	47.53	709.62		CaO = 709.62	
MgO =	2.05	30.61		MgO = 30.61	
CO_2 =	39.53	590.18			CO_2 = 590.18
FeS =	.21	3.14		Fe and S = 3.14	
Fe_2O_3 =	.30	4.48	Fe = 3.136		O = 1.344
H_2O =	1.00	14.93			H_2O = 14.93
	100.00				
Total flux.....		1,493.00			
FUEL					
SiO_2 =	6.98	132.73		SiO_2 = 132.73	
Al_2O_3 =	3.88	73.78		Al_2O_3 = 73.78	
CaO =	.12	2.28		CaO = 2.28	
MgO =	.07	1.33		MgO = 1.33	
P_2O_5 =	.03	.57	P = .25		O = .32
C =	83.27	1,583.46	C = 105.28		C = 1,478.18
FeS =	1.72	32.71	(S = .672	Fe and S = 30.862	
H_2O =	2.86	54.39	(Fe = 1.176		H_2O = 54.39
V. M. =	1.02	19.40			V. Mat. = 19.40
MnO_2 =	.05	.95		MnO = .78(	O = .17
	100.00				
Total fuel.....		1,901.60			
					O = 1,703.67
					N = 5,671.52
Blast		7,396.03			H_2 = 2.32
					O = 18.52
Totals		15,053.63	2,240.00	1,610.355	11,203.275

Detail Calculations per Ton (2,240 lbs.) pig produced. Dry Blast.

Volume of furnace gas (from Balance Sheet).

Carbon in gases = 1,478.18 + (12/44 × 590.18 = 160.96) 1,639.14 lbs.
Carbon in 1 cu. ft. of gas at 62° F. and 30″ Hg. Pressure, .012377 lbs. C.
CO = .07375 lbs. per cu. ft. at 62° F.
CO_2 = .11660 lbs. per cu. ft. at 62° F.
Composition of gases = 22.73% CO
16.33% CO_2
CO = 12/28 by weight of C
CO_2 = 12/44 by weight of C
Then:
CO = .07375 × .2273 × 12/28 = .007184 lbs. C.
CO_2 = .11660 × .1633 × 12/44 = .005193 lbs. C.

.012377 lbs. C.

Gas produced at 62° F. and 30″ Hg. per ton of pig:

$$\frac{1{,}639.14}{.012377} = 132{,}434 \text{ cu. ft. dry gas.}$$

Oxygen in blast (from Balance Sheet).

Oxygen in 1 cu. ft. of dry gas at 62° F. and 30″ Hg. = .023427.
CO = .07375 × .2273 × 16/28 = .009579 lbs. O.
CO_2 = .11660 × .1633 × 32/44 = .013848 lbs. O.

.023427 lbs. O.

Total oxygen in dry gases = 132,434 × .023427 lbs. = 3,102.53 lbs.
This oxygen is derived from oxygen of blast, oxygen in moisture of blast, and oxygen from the solid charge.
Oxygen from solid charges, (dry):

From	Fe_2O_3	=	908.214 lbs.
	SiO_2	=	26.000 lbs.
	P_2O_5	=	4.187 lbs.
	MnO_2, MnO	=	12.634 lbs.
	CO_2	=	429.220 lbs.
	Total	=	1,380.255 lbs.

Oxygen from blast, including moisture in same =
3,102.53 — 1,380.255 = 1,722.275 lbs.

Combustion of carbon.

Carbon burned at tuyeres = 1,722.275 × 12/16 = 1,291.71 lbs.
Carbon burned above tuyeres = 1,478.18 — 1,291.71 = 186.47 lbs.
Percentage of oxydized carbon burned at tuyeres = 87.39%.

Moisture and dry air present in 1 cu. ft. refrigerating-room air.

Water per cu. ft. of air (refrigerating-room) at 36.1° F. (See logs) = 1.56 Grs.
Barometer = 29.44″ Hg.
Pressure above atmosphere in refrigerating-room = 2.47″ H_2O = .18″ Hg.
Total pressure in refrigerating-room = 29.44″ + .18″ = 29.62″ Hg.
Vapor tension of 1.56 gr. H_2O per cu. ft. of vapor, corresponding to dew point of 25° = .130″ Hg.
Absolute pressure of dry air present = 29.62″ — .130″ = 29.49″ Hg.

$$\text{Dry air present} = \frac{29.49}{29.62} \times 1 \text{ cu. ft. refrigerating-room air} = .9956 \text{ cu. ft.}$$

Dry air at 62° F. and 30″ Hg. = .07626 lbs. per cu. ft.
O in air = 23.1% by weight (Richards).
Reducing weight of dry air to 36.1° F. and 29.62″ Hg.:

$$\frac{521.2}{495.3} \times \frac{29.62}{30} \times .07626 \text{ lbs.} = .079231 \text{ lbs.}$$

Oxygen present in dry air per cu. ft. of refrigerating-room air:
.079231 lbs. × .9956 × .231 = .018222 lbs.

Oxygen present in moisture per cu. ft. of refrigerating-room air = 1.39 gr. = .000199 lbs.

Total oxygen per cu. ft. of blast at 36° F. and 29.62″ Hg. = .018421 lbs.

$$\text{Total volume of refrigerating-room air used} = \frac{1,722.275}{.018421} = 93,495 \text{ cu. ft.}$$

Free oxygen present = .018222 × 93,495 cu. ft. = 1,703.67 lbs.

$$\text{Free nitrogen present} = \frac{76.9}{23.1} \times 1,703.67 \text{ lbs.} = 5,671.52 \text{ lbs.}$$

$$H_2O \text{ present} = \frac{93.495 \times 1.56 \text{ gr.}}{7,000} = 20.84 \text{ lbs.}$$

Total = 7,396.03 lbs.

Volume of blast.

Total volume of blast at 36° F. and 29.62″ Hg. = 93,495 cu. ft.
Total volume of blast at 62° F. and 30″ Hg. per ton of iron:

$$\frac{521.2}{495.3} \times \frac{29.62}{30} \times 93,495 \text{ cu. ft.} = 97,138 \text{ cu. ft. standard, wet.}$$

Total air blown at 62° F. and 30″ per entire run:
3,245 × 97,138 cu. ft. (wet) = 315,212,810 cu. ft. wet.

Air at 62° F. and 30″ Hg. (wet), blown per minute net operating time =

$$\frac{315,212,810}{11,427} = 27,585 \text{ cu. ft., wet.}$$

Carbon burned at 62° F. and 30″ Hg.

Total volume of furnace gas at 62° F. and 30″ pressure = 132,434 cu. ft., dry.
CO by analysis, 22.73% = 30,102 cu. ft., dry.
1 cu. ft. CO at 30″ and 62° F. = .07375 lbs.
C in 1 cu. ft. CO at 30″ and 62° F. = 12/28 × .07375 = .031607 lbs.
C in total CO in furnace gas = 30,102 × .031607 lbs. = 951.43 lbs.
C burned to CO_2 = 1,478.18 — 951.43 = 526.75 lbs.

Heat in blast (from 62° F. to 833° F.).

Sensible heat in materials contained in blast:

Material.	Pounds.	Mean Specific Heat B.T.U.	Temperature Interval.	Total B.T.U.
O_2	1,703.67	.219708	771°	288,593
N_2	5,671.52	.251151	771°	1,098,219
Heat in moisture present —sensible	....	....	771°	....
H_2O (vapor)	20.84	.429219	...	6,897
Totals	7,396.03			1,393,709

Composition of furnace gas (from Balance Sheet data).

				Pounds.
N present in gas per ton pig =			N	= 5,671.52
CO present in gas per ton pig — 951.43 lbs. C burned to CO × 28/12 =			CO	= 2,220.00
CO_2 present (from coke) in gas per ton pig — 526.75 lbs. C burned to CO_2 × 44/12		Pounds. = 1,931.42		
CO_2 present (from limestone) in gas per ton pig		= 590.18		
Total CO_2		= 2,521.60	= CO_2	= 2,521.60
H present from water in blast—			H	= 2.32
Volatile matter present from coke—			V. M.	= 19.40
Moisture present—				
	From ore	= 699.13		
	From stone	= 14.93		
	From coke	= 54.39		
	Total moisture	= 768.45	= H_2O	= 768.45
	Total weight of gas			= 11,203.29

Furnace gas produced by calculation from preceding—dry gas.

	Pounds.	Weight Pounds.	Analysis by Weight.	Density.		Volume Cu. Ft.	Analysis by Volume.
CO_2		= 2,521.60	24.20 ÷	.1166	=	207.55 =	16.64
CO		= 2,220.00	21.30 ÷	.07375	=	288.81 =	23.15
H from moisture....	= 2.32						
H from volatile matter, 19.4 × 4/16..	= 4.85						
Total H.......	= 7.17 =	7.17	.07 ÷	.005302	=	13.20 =	1.06
N		= 5,671.52	54.43 ÷	.07377	=	737.83 =	59.15
Totals........		10,420.29	100.00			1,247.39	100.00

In these calculations the volatile matter is assumed to break up into fixed carbon and free H_2.

In comparison with this theoretically calculated gas based on the Balance Sheet data, there is now given—

Furnace gas produced, by actual analysis—dry gas.

	By Volume. Per Cent.		Density.		By Weight. Pounds.	Per Cent.
CO_2	16.33	×	.11660	=	1.904078	23.99
CO	22.73	×	.07375	=	1.676338	21.12
H_2	1.99	×	.005302	=	.010551	.13
CH_4	.04	×	.04228	=	.001691	.02
N_2	58.91	×	.07377	=	4.345791	54.74
	100.0				7.938449	100.0

These two sets of data afford opportunity for observing how closely these total gas products check when obtained from different sources.

In the calculations of "Heat in furnace gases," the weights used will be taken from the "Calculated furnace gas."

Heat in furnace gases, from 62° to 324° F. per ton of pig. (Based on calculated gas analysis.)

Gas.	Pounds.	Mean Specific Heat.	Temperature Interval.	B.T.U.
CO_2	2,521.60	.213160	262°	140,826
CO	2,220.00	.245093	262°	142,556
H	7.17	3.435620	262°	6,454
N	5,671.52	.245093	262°	364,193
Dry furnace gas				654,029
H_2O	768.45	.459758 sensible	262°	92,565
		1056.7B.T.U. latent		812.021
				904,586
Total of wet gas, exclusive of C from volatile matter = 11,188.74				1,558,615

In constructing a total heat balance, the sensible heat entering with the stock must be taken into account. The materials of the charge were each at the average air temperature, i.e., 80.2° F., the base temperature of 62° F. being used as the standard for the heat balance.

In these calculations the total amounts of coke, ore and stone charged into the furnace per ton are used, no deduction being made for flue dust formation, as was done on the Balance Sheet, these materials having their mean specific heats based on the wet state.

Heat entering with charge. (62° to 82.2° F.)

Material.	Pounds.	Mean Specific Heat.	Temperature Interval.	B.T.U.
Ore	4,435.30	.302449	18.2°	24,413
Coke	1,927.10	.212892	18.2°	7,467
Stone	1,497.60	.216026	18.2°	5,888

Similarly, the heats contained in the materials leaving the furnace are required.

Heat contained in flue dust. (62° F. to 324° F.)

Material.	Pounds.	Mean Specific Heat.	Temperature Interval.	B.T.U.
Flue dust	201.2	.194200	262°	10,228

Heat contained in pig iron.

	B.T.U.
Heat in 1 lb. pure iron, from 32° to 2,732° =	450
Heat in 1 lb. pure iron (latent heat in fusion) =	126
	576
Subtract heat from 32° to 62° F. = 30° × .1 specific heat =	3
Heat required to raise iron from 62° to 2,732° =	573
Total heat in 1 ton of pig (62° to 2,732° F.) =	1,283,520

Heat contained in slag.

Heat in 1 lb. slag (Akerman, Bell, Richards) 62° to 2,732° F. = 945 B.T.U.
Slag produced = 1,571.45 lbs. per ton of pig.

1,571.45 × 945 B.T.U. = 1,485,020 B.T.U.

In addition to the sensible heats noted above, we have also to take into account the heats of formation of pig iron and of slag.

Heat of pig formation

From Balance Sheet we find 105.28 lbs. of carbon entering into combination with the iron. This is the reaction of greatest heat value, 1,269 B.T.U.'s per pound of carbon, and will be the only one taken into account.

105.28 × 1,269 B.T.U. = 133,600 B.T.U.

Heat of slag formation.

This is a very difficult matter to give in detail. There is, however, a considerable amount of heat given out when the bases, lime and magnesia, neutralize alumina and silica. This is stated by Richards and LeChatelier as approximately 270 B.T.U. per pound of the combined silica and alumina under the existant conditions.

Total SiO_2 = 514.298 lbs., from Balance Sheet.
Total Al_2O_3 = 249.950 lbs.

764.248 lbs. × 270 B.T.U. = 206,348 B.T.U.

The Heat Balance Sheet will be stated in the following form, it being understood that all heats referred to are calculated from the base temperature of 62° F.:

I. Sensible heat entering the furnace from external sources.
II. Heat developed in the furnace.
III. Heat utilized in chemical reactions in the furnace.
IV. Sensible heat leaving the furnace in outgoing materials.
V. Potential heat in furnace gases as yet undeveloped on leaving furnace.

This latter figure is obtained from the potential heat in the volatile matter in the coke charged = 19.40 × 23,616 B.T.U. = 458,150 B.T.U.
And the heat which may still be obtained by burning the CO in the gas to CO_2 = 951.43 lbs. × 10,205 B.T.U. = 9,709,343 B.T.U.

Total = 10,167,493 B.T.U.

HEAT BALANCE SHEET.

Sensible heat entering from external sources.

	B.T.U.	Per Cent. of Heat Exclusive of Potential Heat in Furnace Gases.		Per Cent. of Total Heat Involved.
Coke, wet	7,467	.06		.03
Stone, wet	5,888	.04		.03
Ore, wet	24,413	.18		.10
Blast, dry	1,386,812	1,393,709	10.18	5.83
Blast, moisture from same	6,897		.05	.03
Total	1,431,477	10.51		6.02
Heat developed in furnace.				
C to CO, 951.43 × 4,375 B.T.U.	4,162,506	30.58		17.50
C to CO_2, 526.75 × 14,580 B.T.U.	7,680,015	56.41		32.30
Heat of pig formation	133,600	.98		.56
Heat of slag formation	206,348	1.52		.87
Total	12,182,469	89.49		51.23
Total heat entering and developed in the furnace	13,613,946	100.00		57.25
Undeveloped heat remaining from fuel	10,167,493			42.75
Grand total	23,781,439			100.00

Sensible heat in outgoing materials.			
Heat in iron..............	1,283,520	9.42	5.39
Heat in slag..............	1,485,020	10.90	6.25
Heat in flue dust...........	10,228	.08	.04
Heat in top gas, dry........	654,029	4.80	2.75
Moisture, sensible heat } in top	92,565	.68	.39
Moisture, latent heat } gas	812,021	5.96	3.41
Total	4,337,383	31.84	18.23
Heat utilized in furnace reactions.			
Reduction of Fe_2O_3, (Fe) 2,086.631 × 3,143...	6,558,281	48.17	27.58
Reduction of SiO_2, (Si) 23.072 × 11,571.....	266,966	1.96	1.12
Reduction of P_2O_5, (P) 3.233 × 10,605.......	34,286	.25	.15
Reduction of MnO_2 to Mn, (Mn) 19.936 × 4,100.....	81,738	.60	.34
Reduction of MnO_2 to MnO (MnO) 3.84 × 871.......	3,345	.02	.01
Reduction of FeS to Fe, (Fe) 1.176 × 772........	908	.01	.00
Expulsion of CO_2 in flux, ($CaCO_3$) 1,266.86 × 812..	1,028,690	7.56	4.33
Expulsion of CO_2 in flux, ($MgCO_3$) 62.54 × 628....	39,275	.29	.17
Expulsion of volatile matter in fuel, 19.40 × 10.92....	21,185	.16	.09
Decomposition of moisture in blast, 20.84 × 5,806......	120,997	.89	.51
Total	8,155,671	59.91	34.30
Loss by radiation, expansion of blast, cooling water, and unaccounted for..............	1,120,892	8.25	4.72
Total heat utilized in and leaving furnace............	13,613,946	100.00	....
Undeveloped heat remaining in gases..................	10,167,493	....	42.75
Grand total.....	23,781,439		100.00

SUMMARY OF TEST.

As was previously explained, the object of a test of this kind on a dry-blast furnace was to arrive at the quantity and heat value of the flue gases passing off from such a furnace under these conditions, and to make a comparison between this value and the pounds of coke consumed per ton of iron by the furnace.

Further, to calculate the *total* heat value of the coke charged into the furnace per ton of iron, then to deduct from this value the quantity of heat passing off in the

flue gases. This difference, together with the heat delivered by the hot blast to the furnace, gives us the total heat required to do the work of reduction, etc., in the furnace.

These results are also compared with the theoretical heat balance results which have been compiled by the use of the molecular heats of formation, etc., of the various substances entering into the furnace burden.

This test has purposely been made as complete as possible. Anyone following the report all the way through could draw his own conclusions, but many will not have the time to do this. We therefore wish to make the following brief comparisons so anyone can obtain in a short time the gist of the whole matter.

Heat value of fuel.

Net coke used per ton of iron = 1,901.6 lbs. This contained 1,478.18 lbs. of carbon to be gasified and 19.40 lbs. of volatile matter.

	B.T.U.
1,478.2 × 14,580 B.T.U. (generated by burning 1 lb. of carbon to CO_2)	21,552,150
19.40 volatile matter × 23,616 B.T.U. (per lb. generated)	458,150
Maximum heat value obtainable from fuel consumed per ton of iron	22,010,300

The following results have been obtained by as many different methods as possible, so there can be no possible doubt of their being approximately correct. The results throughout check each other as closely as could be expected. The best instruments are liable to some percentage of error, and, although analyses were taken as frequently as possible on all materials used in this furnace and on all the products produced, some slight irregularities are liable to enter into a test made on such a large scale.

Gas analyses.

The following gas analyses were obtained from many averages:

	B.T.U. per Cu. Ft.
Calculated from gas analyses (at 62° F. and 30″ Hg.) dry gas	80.55
Calculated from calorimeter analyses (at 62° F. and 30″ Hg.) dry gas	77.27

Cubic feet of air blown (62° F. and 30″ Hg., wet air).

Gross cubic feet of air blown from blowing engines per minute of total running time	32,608

Net cubic feet of air blown per minute of net running time, obtained from Pitot tube in hot blast main	30,015
Net cubic feet of air blown per minute of net running time, from theoretical heat balance	27,585

Cubic feet of gas produced (at 62° F. and 30" Hg., dry gas) per ton of iron.

Cubic feet of gas from Pitot tube in hot blast main	141,451
Cubic feet of gas from Pitot tube in gas flue	135,338
Cubic feet of gas from theoretical heat balance	132,434

To obtain the heat value passing off in the blast furnace gases we will use the results obtained from the Pitot tube in gas main. There is very little difference between the results obtained by the three methods used. The difference between the actual measurements and the results obtained by the theoretical heat balance are easily accounted for by the fact that no scrap was used in burden for compiling the theoretical heat balance.

Heat value of blast furnace gases per ton of iron.

135,338 cubic feet (standard) as obtained from Pitot tube in gas main × 80.55 B.T.U. per cubic foot (standard) gas (average analysis) = 10,901,475 B.T.U. in gas per ton of iron.

Work of reduction, etc.

	B.T.U.
Total B.T.U. in fuel per ton of iron:	
Carbon to CO_2, 1,478.2 × 14,580 B.T.U.	21,552,150
Heat from volatile matter, 19.40 × 23,616 B.T.U.	458,150
Total heat available from fuel	22,010,300
Calorific value of blast furnace gas produced	10,901,475
Heat remaining from fuel, which added to the heat of the hot blast is the total heat required for doing the work of reduction, etc., and heating up the products	11,108,825

In comparison with this the figures from heat balance are as follows:

	B.T.U.	
Heat utilized in furnace, including furnace radiation losses, etc.		13,613,946
Heat from hot blast	1,393,709	
Heat from coke	7,467	
Heat from stone	5,888	
Heat from ore	24,413	
Heat from pig formation	133,600	
Heat from slag formation	206,348	
	1,771,425	1,771,425
		11,842,521

Total useful heat in gases, due to their fuel value.

		B.T.U.	
Due to analyses and quantity		10,901,475	
Due to 80% of the useful sensible heat imparted to gases by their passage through furnace burden:			
Sensible heat in dry furnace gas	654,029		
Sensible heat in moisture of same	92,565		
Then .8 ×	746,594 =	597,275	
		11,498,750	11,498,750

The following are estimates of the heat required by the furnace under present conditions:

Heat used by stoves at 60% efficiency = $\frac{1,393,709}{.60}$	2,322,850	
Total to run furnace; 1,858 B.H.P. hours × 55,800 B.T.U. (per B.H.P. at 60% efficiency) × $\frac{24}{405.62}$	6,134,400	
10% loss due to leakage of gas, steam condensation, blowing off boilers and miscellaneous losses......	1,149,875	
Total to deduct......................	9,607,125	9,607,125
Surplus heat in gases available for other work.....		1,891,625

This total surplus gas might be considerably increased by providing suitable means of reducing the waste heat in the stove stack gases, resulting in an efficiency of 70 per cent., and by supplying the power requirements of the furnace by gas engines.

When using washed gas on stoves and gas engines, which is necessary to secure the higher efficiency, the sensible heat in the foregoing calculation is lost (597,275 B.T.U.).

Assuming that with gas engines the total power required would be the same as before, the balance becomes:

		B.T.U.
(Brought forward)...............................		10,901,475
Heat used by stoves, with economizers for stack gas at 70% efficiency; $\frac{1,393,709}{.7}$ = ...	1,991,010	
Total to run furnace; 2,503 I.H.P. × 12,000 B.T.U. (B.T.U. per gas engine I.H.P.) × $\frac{24}{405.62}$ = ...	1,777,200	
	3,768,210	3,768,210
Surplus heat in gases, etc................................		7,133,265

Coal value of surplus gas.

As a matter of interest we add the comparative values of the surplus gas remaining under the last condition exhibited, when stoves of 70 per cent. efficiency and gas engine equipment are used, based upon coal at various

prices. It should, however, be borne in mind that the actual value of the furnace gas is somewhat higher than the comparative B.T.U. would indicate, owing to the fact that the gas does not require handling and that it produces no ashes or clinker demanding labor in disposal.

Bituminous coal, having an approximate calorific value of 14,000 B.T.U. per pound, is here taken as the standard. The weight of coal equivalent to the surplus gas produced per ton of iron is

$$\frac{7{,}133{,}265}{14{,}000} = 509.52 \text{ lbs.}$$

This represents a credit value per ton of iron produced with coal at the various prices as follows:

$$\text{Coal at \$1.50 per ton: } 509.52 \times \frac{\$1.50}{2{,}000} = \$0.3821$$

$$\text{Coal at \$2.00 per ton: } 509.52 \times \frac{\$2.00}{2{,}000} = .5095$$

$$\text{Coal at \$2.50 per ton: } 509.52 \times \frac{\$2.50}{2{,}000} = .6369$$

$$\text{Coal at \$3.00 per ton: } 509.52 \times \frac{\$3.00}{2{,}000} = .7643$$

This estimate of heat required for work in the furnace is only added as a matter of interest, as necessarily some assumptions were made regarding various losses. However, these assumptions regarding these losses have been made as low as experience in this class of work would permit.

Direct Reduction in a Blast Furnace.

The economical importance of reducing ores in a blast furnace, principally by carbon monoxide (CO), is well understood by blast furnace men, as reduction effected by carbon at the tuyeres is very uneconomical, requires a great quantity of heat and abstracts this heat from a point in the furnace where it is most needed. This we try to avoid as much as possible by proper furnace lines, good distribution, and making all other conditions

as uniform as possible. Anything that tends to consume coke in the upper part of the furnace should also be avoided, because there will remain less coke for combustion at the tuyeres, where the greatest heat is needed. Soft coke or coke-dust is more readily affected by CO_2 than hard coke, resulting in greater loss.

THE USE OF HOT BLAST AND ITS RELATION TO BLAST FURNACE PRACTICE.

In the lower part of a blast furnace carbon is oxidized only to carbon monoxide (CO), which generates 4,375 B.T.U. per pound of carbon, but when complete combustion takes place to carbon dioxide (CO_2), 14,580 B.T.U. are generated. Therefore the heat generated by a unit of carbon in heating the blast is three and one-third times as great as that generated by a unit of carbon burned in the blast furnace.

The use of hot blast increases the temperature and efficiency of combustion near the tuyeres of a blast furnace, causes the carbon to be quickly converted into carbon-monoxide, and also localizes the heat of combustion. Heat supplied to the furnace by the more complete burning of carbon outside the hearth in the stove allows the amount of coke charged to be greatly decreased, consequently a smaller quantity of blast is required, the upper part of the furnace is cooler, radiation losses are lessened, and less sensible heat is carried away in the escaping gases. One of the greatest advantages of hot blast consists also in the intense local heat produced in the hearth, this intensity controlling to a great extent the rate of heat transfer to the descending materials, and the efficiency and speed of the smelting. This matter of local heat intensity is of great interest, as it accounts for savings due to high blast heats that could not otherwise be explained on the basis of actual heat units added to the hearth by the preheated blast.

The diminished amount of fuel required by the use

of high heats yields a smaller quantity of slag from its ash, and requires less limestone for fluxing. A furnace of a given capacity contains more ore, and its production is, therefore, increased.

At the present time in this country, every blast furnace manager is trying to obtain all the advantages possible, such as better quality of product, lower cost of production, and a larger tonnage, by the use of high heats, but there is a limit as to how far this can economically be carried out.

With some furnaces having bad distribution, badly worn lines, etc., it is found impossible to make use of high heats, such as 1,200° or 1,300° F., and obtain these greater economies; but with good distribution and well-proportioned furnace lines in good condition, these heats can be easily carried most of the time and the economies effected; however, it is essential that operating conditions be kept as uniform as possible, and it may be especially noted that any irregularity in volume, pressure, or temperature of blast has decided effects on the maximum degree of heat it is subsequently possible to carry on any given furnace, and still maintain smooth working.

One of the savings due to higher heats comes from the ability to carry more acid slags. The temperature at the tuyeres is more efficient in the removal of sulphur; also, on account of the lower coke consumption, we have less sulphur to remove. The ability to run more acid is a great benefit to successful blast furnace operation, as basic slags gradually cause lime to collect on the bosh, causing scaffolds and frequent cleaning-offs, all of which cause bad furnace operation. Of course our ability to run on acid slags depends to a certain extent on the sulphur in the burden, and the cinder volume being carried.

Volume of Blast Furnace Gas.

There is a definite amount of fuel gas passing off from a blast furnace, corresponding to its fuel consumption, which has a definite fuel value. This gaseous fuel has a

much greater commercial value than an amount of coal containing an equal number of B.T.U., as it does not require the expense "handling," and it is an ideal fuel for boilers in generating steam, or for use in gas engines.

On this account we naturally wish to burn this fuel very economically in our stoves, so as to conserve as much as possible from the balance of gas left over for other useful purposes. It is for this reason blast furnace operators are giving so much thought to the design of the most economical stove to fulfill these conditions.

There are many types of stoves, such as the two-pass, three-pass, and four-pass, which give excellent results when well constructed. In regard to stoves the problem is to get as simple a stove as possible, having the required strength, with the greatest amount of well-arranged heating surface, so that all the heat possible will be absorbed from the passage of the burnt gases through its checkers, and that this heat will also be readily given up to the air during its passage through the stove. To better obtain these results the tendency is to decrease the size of checker openings, and most of the newer stoves have from 5″ to 6″ checker openings in place of the customary 9″ openings.

Tests show the greater heating effect of the surface of a stove brick, compared with the interior.

In the design of a stove, checker walls should be as thin as is consistent with the structural strength, and size of checker openings should be as small as operating conditions will permit, as the surface of the brick exposed to the passage of the heated gases is of primary importance in a stove, and the thickness of walls and size of checker openings should be reduced to a minimum, considering the structural strength of brickwork required in any stove design, and the ability to clean the checker openings.

A modern blast furnace equipped with four well-designed stoves 22′ in diameter, 100′ high, having 60,000 square feet of heating surface each, should have no

trouble in running on a straight line heat of 1,200° F., and still have plenty of reserve in case it is demanded by the furnace. The average stack temperature from such stoves should be below 400° F., nor should it be necessary to install five stoves in place of four if washed gas be used.

We will now consider a test run on one of such modern stoves:

EFFICIENCY TEST ON A 22′ 0″ × 100′ 0″ HOT BLAST STOVE.

Object of Test.—The primary aim in view when testing this stove was to obtain data on which to base future improvements, either in the construction or operation of hot blast stoves in order to obtain increased heat efficiencies; and, if possible, a decreased equipment; to also obtain data on the comparative efficiency of this type with the older types of stoves in use; and to know accurately the quantity of gas being consumed in our blast furnace stoves. We also aimed to run this test over a long period of time in order to compare with former stove tests made on short runs.

Description of Stove.—The stove is an improved two-pass Cowper type, outside diameter of shell 22′, height over all 100′. A gas burner is used of the Spearman type. The hot-blast nipple and water-cooled hot-blast valve used were also of standard type and size. Fig. 4 shows a general arrangement of the stove. The combustion chamber is roughly elliptical in shape, 10′ 11¾″ on the major axis, 4′ 11″ on the minor axis, and rises vertically to the dome of the stove, having an area of approximately 42 square feet. The gas enters on the minor axis of the combustion chamber, this axis being placed radially from the center of the stove. The combustion chamber is separated from the checker chamber by a 22½″ fire-brick partition, which rises 18″ above the top of the checkers to form the bridgewall.

The checker chamber which fills the remaining space below the dome is filled with 15″ × 7½″ × 3″ checker brick laid as shown in Fig. 4. The stove is provided with three standard chimney valves having openings 20½″ in diameter, two of which open directly into the shell, the third opening into a cast iron tee. The cold blast enters through this tee, as shown in Fig. 4, and is supplied by a 2.99′ internal diameter cold blast line.

Former Tests on Various Types of Hot Blast Stoves.—We consider the stove described above one of the best and most modern of its class, and its efficiency of approximately 60 per cent. is excellent. However, in following through this test you will find numerous defects in its performance pointed out. We have stove tests on two-, three-, and four-pass stoves, all of which show numerous short-comings, so that which type of stove is the best is a question that has often to be decided. The results of the test given furnish us with information that will aid in determining this as well as helping in obtaining still higher efficiency from hot blast stoves in the future. The use of clean gas is a great aid in this direction, as it was impossible to attempt these improvements when dirty gas was being used on stoves.

Description of Apparatus.—During the erection of the stove, holes were drilled through the shell and brick work at three levels, namely, about 18″ above the bottom of the checkers, at the center level of the checkers, and 18″ below the top of the checkers, and through the dome above the center of the combustion chamber. These holes were provided with hat flanges having 4″ openings. A 4″ diameter hole was cut in the shell under each flange, and a 1½″ diameter hole through the brick work.

One hole opened through the dome directly above the center of the combustion chamber. Three holes opened into the combustion chamber through the sides, and were cut radially on the minor axis of the combustion chamber. Three holes opened into the checker chamber

diametrically opposite the holes in the combustion chamber, and three more were cut into the checker chamber on the diameter 90° from the other two holes. The center lines through all the holes passed through the center line of the stove. The checker brick opposite the holes communicating with the checker chambers were drilled, having 1½″ diameter holes through them. These openings formed continuous passages from the shell to the diametrically opposite brick walls, giving six passages through the checkers on 90° diameters, and four openings into the combustion chamber. Balconies and platforms with the necessary approaches were erected at the required levels as shown on Fig. 4. The location of these holes are also shown. The gas main, cold-blast line, hot-blast nipple, chimney valves and burner base were provided with the necessary holes for admitting the apparatus as listed below.

Recording pressure gauges were connected to read the following pressures:

Cold blast entering stove, fuel gas entering stove, and draft in chimney valves; also the draft in the combustion chamber at the gas burner. Recording thermometers were connected to give the temperature of the fuel gas in mains, and the cold blast. Recording pyrometers were connected to give the temperatures of the stack gases at the chimney valves. Recording differential gauges were connected to double bent pitot tubes in the gas main, and the cold blast line, to give the quantities of fuel gas and blast used. A calibrated indicating pressure gauge was connected to the cold blast line. Ellison multiplying gauges were connected to give the pressures in the gas main, draft in chimney valves, draft in the combustion chamber and at different places, at various times during the test for checking purposes. Calibrated indicating pyrometers were used to give the temperatures of the hot blast, of the gases at various points in the combustion chamber and checkers, and at the chimney valves. Calibrated mercurial thermometers were used to give the

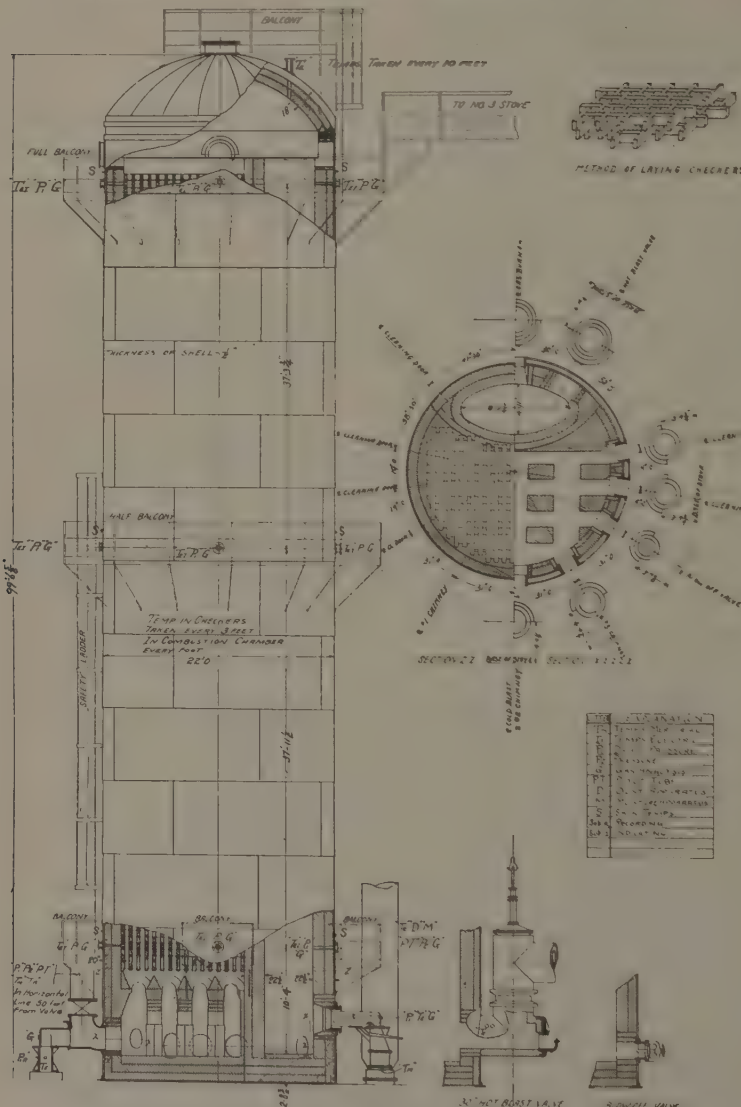


FIG. 4.

temperature of the gas in the mains, the cold blast, dry and wet bulb air temperatures, and for checking and correcting meter readings, etc. Calibrated mercurial thermometers were used to obtain the skin temperatures of the stove. Ellison multiplying differential gauges were used to check the pitot tube pressures.

Continuous and snap gas samples were taken over acidulated water contained in two five-gallon glass carboys connected to form an aspirator. Samples were taken at the gas main, chimney valves, in the checkers, and in the combustion chambers. The samples were transferred from the carboys to 200 cc. metal sample cans and analyzed in the gas apparatus in use at the plant (a modified form of Orsat).

Dust and moisture determinations were made at stated intervals for the dust and moisture contents of the fuel gas consumed. The United States Steel Corporation standard apparatus was used in making these determinations.

Fig. 4 shows the location of the various points and the readings taken at the same. A standardized mercurial barometer was used during the tests.

General Methods.

The general method of running the tests was as follows:

After starting all recording instruments on Monday mornings and taking the necessary check readings on all instruments, if all conditions were favorable the test was started the first time the stove was taken off the furnace, and the final hot-blast temperature noted. The test was then run continuously regardless of the furnace or blast conditions until the following Saturday or Sunday morning, whenever conditions could be brought to a final balance; and the test was stopped when this balancing point, that is the same hot-blast temperature, was reached.

The recording instruments were maintained in continuous service throughout the run, charts being changed every 24 hours. Check readings on the indicating instruments were taken every 20 minutes, and the recording instruments corrected if necessary. Fuel gas samples were started about 10 minutes after the gas was ignited, and a continuous sample taken up to within 5 to 10

minutes before withdrawing burner. Continuous chimney gas samples were taken at the same time from each chimney valve in service. These continuous samples were taken every time the stove was on gas. Dust and moisture determinations were made on the fuel gas, once each time the stove was on gas. During the time the stove was on blast, check readings on all air instruments were taken every 20 minutes, and temperature readings of the hot blast were taken with an indicating pyrometer every minute for the first 10 minutes and every 5 minutes thereafter. These readings were checked at intervals by placing another complete pyrometer in parallel and reading both instruments at the same time.

Discussion of Tests.

Table 1 (see page 62) gives a tabulation of the results of four six-day tests. The usual methods of calculation were used with the exception of the calculation for radiation. This item was calculated from the following formula: B.T.U. per minute = .03 × temperature difference inside and outside of wall × height of stove × [(diameter of stove — thickness of wall) ÷ thickness of wall.] The original data were taken from the charts by averaging the records obtained, and used after making all corrections. The tests include time lost for changing tuyeres, cleaning stoves, casting, checking, etc. The cold-blast mixing valve was open more or less during all the tests. Tests 1, 2, and 4 were run on two stack valves and 3 with three stack valves.

It should be borne in mind that these tests are under actual working conditons and include all of the abovementioned disturbing factors in distinction from previous short tests made under better conditions. These tests show stove efficiencies of from 56.32 to 60.79 per cent. (item 78).

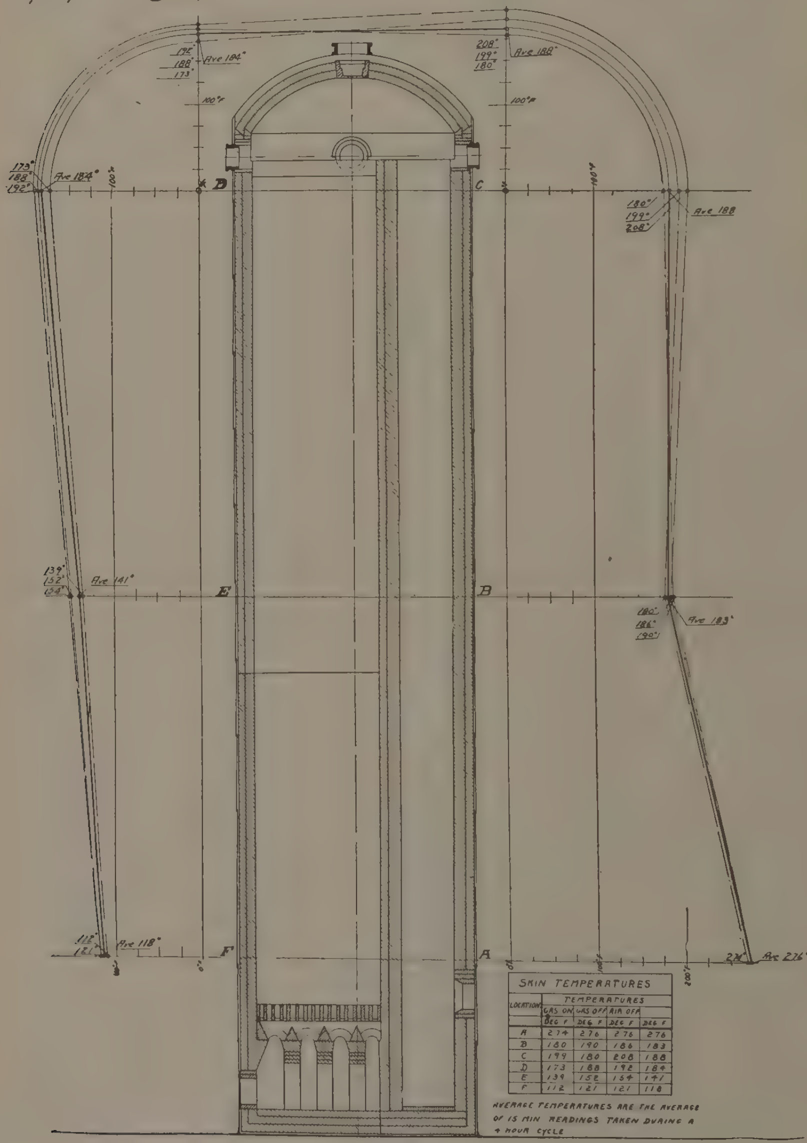
Comparing tests 1, 2 and 4 with a range of from 30,735 to 37,744 cubic feet of air per minute and using two chimney valves, with test 3 with 39,035 cubic feet of

air per minute, using three chimney valves we find that 3 shows a gain of 2.75 per cent. in efficiency above the best test on two valves, and a saving of approximately 5 per cent. in unaccounted-for losses. These losses cover stove changes, cooling water, loss of gas, etc. During the runs with two valves there was a continual escape of flame from the stove to the atmosphere around the burner. This was entirely stopped when running with three valves. The test with three valves shows a slight increase in the rate of flow of gases passing through the stove, namely, 5,277,841 pounds in 98.064 hours, or 53,820 pounds per hour against an average of 53,103 pounds per hour for the tests with two valves. This difference of flow should have been larger, but the gas pressure and heat value of the gas was slightly lower during this run, and in spite of the increased draft in the combustion chamber the total stack gas did not show a sufficient increase to determine the effect of an increased velocity on the efficiency.

Items 66 and 67, and 36 and 37 in Table 1 show weights of gas and blast through the stove and the time during which these weights passed through the stove. These show an average flow of gas of 53,282 pounds per hour through the stove against an average flow of 166,174 pounds of air per hour. The gas yields from 76 to 78 per cent. of its total available heat to the stove, and the air withdraws from 56 to 60 per cent., so that the air withdraws the heat from the stove nearly three times as fast as the gas delivers the same.

Skin Temperatures.—Skin temperatures of the shell of the stove were taken by attaching well-insulated wooden mercury wells to the stove at the points marked S on Fig. 4. These cups or mercury wells were made by drilling a half-inch hole deep enough to hold a thermometer in the center of a block of wood, and then splitting the block through the center to make two half wells. After attaching to the stove, the shell formed the remaining side of the cup. The wells were filled with mercury

and then insulated from the air. The mercury would then give approximately the temperature of the shell at the point of attachment. Simultaneous readings were taken every 15 minutes at the six points marked A, B, C, D, E, F, in Fig. 5, during several complete four-hour cycles,



LOCATION	TEMPERATURES			
	GAS ON	GAS OFF	AIR OFF	
	DEG F	DEG F	DEG F	DEG F
A	274	276	276	276
B	180	190	186	183
C	199	180	208	188
D	173	188	192	184
E	139	152	154	141
F	112	121	121	118

FIG. 5.

and at one or two of these points at additional intervals during the tests. The change in temperature at any one point during a cycle, as shown in the table on Fig. 5, was not over 30° at the maximum point of change and usually much less, and the variation from cycle to cycle was also less.

The temperatures found during an average cycle are plotted on Fig. 5. These curves are plotted with the O° line running parallel to the vertical sides of shell, and through the points C. D. at the top of the stove. Arcs of circles and straight lines across the top connect the corresponding points of the two sets of vertical curves. The average temperature is shown as a heavy line, and the temperatures for gas on, gas off before air was turned on and air off before gas was turned on are shown as dot and dash lines.

These curves show the maximum reading at A. The true maximum temperature was probably at a point between A and B, as the maximum internal temperature was found to be about 65 feet from the top of the stove.

The curves show that the highest skin temperatures are on the combustion side, as would be expected, and near the bottom. The skin temperature from B to D is probably nearly constant, and the temperatures on the checker side fall along a curve which is probably some function of the internal temperature.

These curves show us that the best stove construction, as determined from the skin temperature, which naturally is some function of the radiation (the radiation varying as the difference between the fourth powers of the absolute temperatures according to the Stefan Boltzman law for black bodies), would be some form of the center combustion stove. Or that if the side combustion stove is preferred for other reasons, the loss by radiation, which on this stove is approximately 10 per cent., could probably be reduced 50 per cent. by the use of some insulating substance which would have to be heavier on the combustion chamber side. Of course the amount of heat loss by

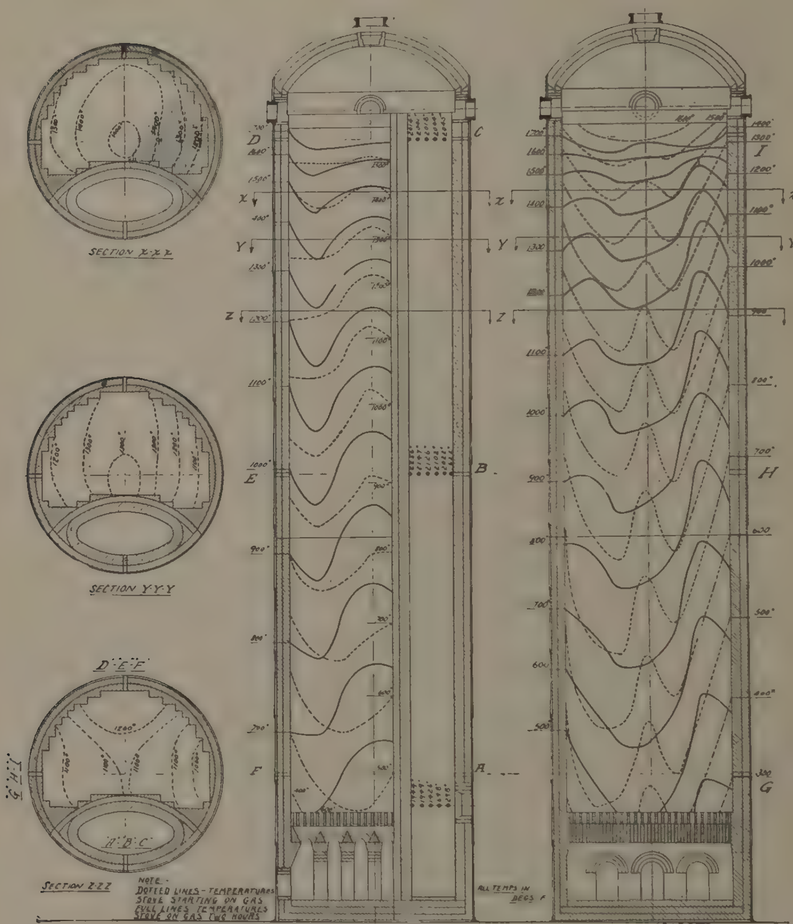


FIG. 6.

radiation which could be saved by insulation would depend on the allowable rise of temperature above the present temperatures in the stove, this rise depending on the fusibility of the brick and its life under higher temperature and the possible temperature obtainable by the combustion of blast furnace gas. The allowable thickness, etc., would have to be determined by experiment, and by considering the cost of the insulation required and the value of the heat saved.

Checker Temperature Curves.—A series of tempera-

tures were taken in the checker work of the stoves. These were taken at three levels, through holes left in the shell and the checkers as previously described. These temperatures were taken approximately every three feet, the distance being laid out to place the end of the couple approximately in the center of a channel and to get temperatures in the geometrically central channel of the stove. Temperatures were taken during twelve cycles, and the isotherms shown on Fig. 6 were drawn from the temperatures as found on the two average cycles whose center temperatures were approximately the same. Although the couples were threaded through heavy iron pipe with the hot junction left exposed to the gases, great difficulty in handling and maintaining the insulation was experienced. Some of the trouble was due to supporting the 24-foot couples used, when overhanging the platform, although the ends were swung from the upper galleries and from supports; some were due to handling the heated couples and others due to the breaking of the insulation. These were finally overcome. All tests having doubtful readings or on which couples broke down were thrown out and not considered.

The general procedure was as follows: Temperatures were taken through holes D, E, and F, Fig. 6, simultaneously in the same channels during one run, and through G, H, and I simultaneously in the same channels during another, etc. Other readings were taken simultaneously through the holes B, C, and D; C, D, and E; C, D, and I, at different times for tying the various runs and readings together. Other conditions on the stove were nearly the conditions as found during the tests.

Temperature readings were taken only during the time the stove was on gas as we encountered special difficulties in attempting to take readings under blast, due mainly to leakage under the high pressure, and the difficulty of handling the instruments under these conditions with hot blast escaping around them.

As soon as the stove went on gas the holes were opened

and the couples inserted to the first position. We found that the couple indicated the temperature in about two minutes. To make certain of the readings, however, the couples were allowed to remain in position for five minutes before taking the readings. The couples were then pushed to the next position and read after five minutes, and so on from position to position back and forth across the stove until about 20 minutes before the stove went on air, when the couples were withdrawn and the holes made tight.

After making all corrections, the simultaneous readings taken in the same channel were plotted to temperature and position ordinates and connected by a curve. The approximate points for each 100° from 400° to 1,700° were then located and marked on the cross section of the stove. This was done for the series of readings across the checkers and the isotherms for that series drawn by connecting points of equal temperature. The dotted lines on Fig. 6 are the isotherms for the first series of readings after the stove went on gas, and the full lines are for the series taken two hours later.

The curves shown in the sections x-x-x, y-y-y and z-z-z were obtained by locating the points where the isotherms crossed these planes and then connecting these points by a series of isotherms. These isotherms are only approximate as readings were only taken on two diameters at right angles. In section x-x-x the area completely enclosed by the 1,400° isotherm has a temperature below 1,400°, and the area enclosed between the 1,400° isotherms has a temperature above 1,400°, and the area enclosed between two isotherms of different temperatures is at a temperature below the higher and above the lower. The same applies to the sections y-y-y and z-z-z.

On studying these curves we note the following, remembering that the gases are traveling downward. The isotherms in the section through D, E, F have their low points nearer the shell than the combustion chamber, and in the section through G, H and I the low points are near

the center. The distance between the isotherms for the same temperature at the start and two hours later is variable and is greatest nearer the shell than the combustion chamber. The distance is proportional to the speed of heating of the checker work, the greater the distance the more rapid the heating, and conversely. The gases enter the dome and checkers at temperatures which are fairly even across the combustion chamber as shown by the temperatures at C and over the area of the checker chamber as shown by the 1,700° isotherms. The rate of transmission and the amount of heat transmitted as shown by Luche, Jordan and others for gases, to solids, or liquids, and opposite, varies directly as some function of the weight of gas flowing per second per unit of area of the conduit. Then those areas of the checkers which are heating more rapidly than others have more gases flowing through them. These curves then show a very uneven distribution of the gases flowing through the checkers and that the greatest flow is at or near the shell, and probably has its maximum flow in an area approximating a circular band following the outline of the shell.

The dotted isotherms also indicate the thermal condition of the checkers after passing the blast, and show that the blast is also poorly distributed, especially as the heavy flow is nearer the combustion chamber distributing mainly through the center and sides on section G, H, I. This poor distribution of the flow of gases is very serious in its effects, especially as the concentrations of the flow of gas and air are in different parts of the checker work. This tends to give lower stove efficiency, due to poor heat interchange between gas and air and increased radiation losses due to higher temperatures near the shell.

Location of Maximum Temperature in the Combustion Chamber.—A number of tests were made at different times to locate the maximum temperature point in the combustion chamber. Table 2 shows the average results of these temperatures. This locates the maximum point 65 feet from the top of the stove, or about 16 feet below

the openings at the center of the checkers. That is hole B on Fig. 6. These temperatures were taken with an 80-foot couple which had to be reinsulated after the completion of each run. The couple was dropped through the opening above the center of the combustion chamber, and readings taken every ten feet.

Gas Analysis and Dust and Moisture Tabulations.—Table 3 gives the fuel gas analyses; Table 4, the corresponding stack gas analyses, and Table 7, the corresponding dust and moisture determinations. These tables are appended to show the fuel and combustion conditions that were obtained during these tests.

Gas Analysis in Checker Chamber.—Table 5 shows two series of analyses made on the gases in the checker chambers. The series on November 26 are given to show one of the few cases found where combustion was not complete before the gases reached the checkers.

In the series for December 1 it will be noticed that the gases towards the shell show a higher density at these points. We also call attention to the variations in analyses taken at the same time at different parts of the stove and at the chimney valves.

Gas Analyses at Different Points.—Table 6 shows analyses of the gases at different points in the combustion chamber and checkers, and corresponding fuel gas analyses. It will be noticed that the gas burned progressively in vertical layers, that the samples above the burner always showed poorer combustion than at the burner level, and that combustion was not complete until the gases had passed into the dome of the stove.

Gas Burner.—Throughout the runs it was found that the gas was burning explosively, vibrating the stove and its surroundings, and throwing out flame around the burner. All pressure instruments in connection with the gas system showed the effects of this vibration. This vibration was actually traced from the chimney valves to the gas in the mains approaching the stove. We noticed

that this vibration increased in rapidity with three chimney valves, but not in intensity.

In connection with the burner a whirling device was here added. This slowly whirled the air entering the burner. We found that this decreased the vibrations in the combustion chamber and allowed a decrease in the air supply so that the chimney gas analysis with these valves on showed an average of from 1.6 to 2.4 per cent. O_2 with no CO, that the combustion chamber temperature at the 50-foot level was increased by from 50 to 75° F., and that the stove continually increased in temperature. We made repeated attempts to obtain a complete eight-hour test with this burner, but the conditions at the furnace were such that the blast was very unsteady, and it was not possible to obtain a balance on the stove as the final temperature of the blast was from 100° to 150° higher at the end of the test than at the start, and even when holding the stove for 15 minutes past its regular time, no balance could be obtained. In connection with the temperature work in the checker chamber, we attempted to take pitot tube readings at various points to obtain the actual velocities of the gas at these points. The vibrations of the gas were so severe that we found it impracticable to obtain any readings of value.

Summary of Test.

(1) That improvement can be made in the distribution of gases through the checker work of the stove. The dome does not fully accomplish this. It may be possible that a baffle or change in bridge-wall height could be added to advantage in the dome.

(2 That the stove gives better efficiency when using three chimney valves.

(3) That prolonged tests are practicable and give much more reliable results on which to base conclusions than do short tests.

(4) That a much more efficient burner can be perfected so as to get more efficient combustion. It may require

gas and air regulators in order that we can premix just the right quantities of gas and air to obtain the best efficiency.

(5) The velocity of the gas passing through the stove is very low compared with that of the air, and that the air withdraws the heat from the stove much faster than the gas supplies the heat. This ratio is approximately that of the weight of gases flowing per hour.

(6) Loss from chimney gases (approximately 20 per cent.) is well worth saving by heat exchangers for preheating the blast before its entry into the stove or for preheating the air used for combustion of the gases burned in the stove. A very desirable arrangement would be a fan under slight pressure to force the air required for stove burners through a preheater of this kind. All the mixing should be done in the burner. The additional temperature of air and the slight forced draught would aid greatly in obtaining a higher combustion temperature in the lower part of the combustion chamber, shorten the flame, and confine all the combustion to the combustion chamber, so that the hot products of combustion alone will pass through the checker work. In many cases the combustion is not complete at the top of the checkers.

(7) Radiation losses amount to from 7 to 12 per cent. from the exposed surface of the stove. It may be possible to find a more efficient insulation between the brickwork and the shell.

TEST OF HOT BLAST STOVE.

TABLE 1—RESULTS OF TESTS.

1. Number of test	1	2	3	4
2. Date of test	9/15 to 9/21/13	10/28 to 11/1/13	11/3 to 11/9/13	11/10 to 11/16/13
3. Blast furnace and stove number	"G" No. 4	"G" No. 4	"G" No. 4	"G" No. 4
4. Size of stove	22'×100'	22'×100'	22'×100'	22'×100'
5. Type	Two Pass	Two Pass	Two Pass	Two Pass
6. Heating surface in checkers, sq. ft.	51,192	51,192	51,192	51,192
7. Cubic contents in checkers, cu. ft	8,894	8,894	8,894	8,894
8. Ratio of heating surface to cubic contents of brickwork in checkers	5.75:1	5.75:1	5.75:1	5.75:1
9. Estimated weight of brickwork in stove, lbs.	3,617,000	3,617,000	3,617,000	3,617,000
10. Estimated weight of iron in stove, lbs.	223,000	223,000	223,000	223,000

PRESSURES.				
11. Blast furnace gas in main, In. H_2O	3.46	2.70	2.60	2.85
12. Draft in combustion chamber, In. H_2O	....	.72	1.25	.92
13. Draft in chimney No. 1, In. H_2O	1.38	1.51	1.45	1.48
14. Draft in chimney No. 2, In. H_2O	Not on	Not on	1.50	Not on
15. Draft in chimney No. 3, In. H_2O	1.40	1.66	1.54	1.56
16. Average draft at chimneys, In. H_2O	1.39	1.58	1.47	1.52
17. Blast in main, lbs. per sq. in....	13.45	14.87	16.90	16.84
18. Barometer at 32° F., In. Hg.......	29.500	29.380	29.239	29.280
AREAS.				
19. Burner opening, sq. in..........	165.29	165.29	165.29	165.29
20. Area of gas leg, sq. in...........	1,366.36	1,366.36	1,366.36	1,366.36
TEMPERATURES.				
21. Blast furnace gas in main, degs. F.	85.52	63.21	67.42	57.94
22. Cold blast in main, degs. F.......	178.0	163.5	172.5	160.5
23. Hot blast in main, deg. F........	1,356.0	1,218.0	1,183.0	1,200.0
24. Gases No. 1 chimney (min.), degs. F.	390.0	459.0	437.0	391.0
25. Gases No. 1 chimney (max.), degs. F.	600.0	612.0	590.0	589.0
26. Gases No. 1 chimney (ave.), degs. F.	519.0	563.0	540.0	537.0
27. Gases No. 2 chimney (min.), degs. F.	Not on	Not on	395.0	Not on
28. Gases No. 2 chimney (max.), degs. F.	Not on	Not on	695.0	Not on
29. Gases No. 2 chimney (ave.), degs. F.	Not on	Not on	545.0	Not on
30. Gases No. 3 chimney (min.), degs. F.	400.0	374.0	403.0	360.0
31. Gases No. 3 chimney (max.), degs. F.	640.0	531.0	570.0	596.0
32. Gases No. 3 chimney (ave.), degs. F.	536.0	488.0	515.0	538.0
33. Chimney gases, total ave., degs F.	527.5	526.0	533.0	537.5
34. Atmosphere, wet bulb, degs. F...	63.71	44.43	50.26	42.17
35. Atmosphere, dry bulb, degs. F...	69.08	47.73	55.48	44.84
DURATION.				
36. Time stove on gas, hours.........	95.481	72.488	98.064	100.398
37. Time stove on blast, hours.......	35.771	27.145	34.949	35.080
38. Total elapsed time for test, hours	136.100	103.908	140.000	140.633
GAS.				
39. Heat value per cu. ft. of dry gas at 62° F. and 30″ Hg. (gross), B. T. U.	94.63	93.03	88.51	95.11
40. Grains of moisture per cu. ft. at 62° F. and 30″ Hg.	7.410	5.69	5.55	4.86
41. Grains moisture per cu. ft. as actually existed in main, grains	7.03	5.59	5.41	4.87
42. Total gas consumed at condition in main, cu. ft.	28,701,589	25,139,665	31,341,274	30,528,654
43. Total gas consumed at 62° F. and 30″ Hg., cu. ft.	27,237,808	24,687,151	30,604,754	30,623,293
44. Gas consumed per min. at temperature and pressure in main, cu. ft.	5,010	5,780	5,326	5,069
45. Gas consumed per min. at 62° F. and 30″ Hg., cu. ft.	4,754	5,676	5,201	5,084
46. Total moisture in gas consumed, lbs.	30,395	20,061	24,227	21,248
47. Grains of dust per cu. ft. at 62° F. and 30″ Hg., grains	0.0719	0.0811	0.1385	0.1876
48. Grains of dust per cu. ft. as actually existed in main, grains	0.0682	0.0802	0.1352	0.1882
49. Total dust in gas consumed, lbs..	156.52	286.02	605.50	814.02
BLAST.				
50. Total air blown at condition in main, cu. ft.	42,959,540	36,754,254	46,590,295	45,920,948
51. Total air blown at 62° F. and 30″ Hg., cu. ft.	65,964,374	59,714,636	81,854,489	79,443,240
52. Total air blown per min. at 62° F. and 30″ Hg., cu. ft.	30,735	36,664	39,035	37,744

53. Grains of moisture per cu. ft. at conditions in main, grains......	9.03	4.83	6.27	5.23
54. Total dry air heated, lbs..........	5,030,347	4,611,814	6,150,198	6,162,178
55. Total moisture heated, lbs........	36,086	25,397	41,745	34,303
ATMOSPHERE.				
56. Grains of moisture per cu. ft., grains	5.8800	2.9754	3.5408	2.9654
57. Humidity, per cent................	76.10	75.50	70.20	79.93
58. Total dry air entering stove for combustion, lbs..................	2,301,734	2,479,571	2,868,633	2,834,483
59. Total moisture entering stove with air for combustion, lbs..........	16,399	13,869	19,480	15,757
TOTAL QUANTITIES.				
60. Total weight of dry gas consumed, lbs........................	2,043,553	1,840,827	2,309,350	2,290,046
61. Total weight of dry air for combustion, lbs......................	2,301,734	2,479,571	2,868,633	2,834,483
62. Total weight of moisture entering stove during combustion, lbs...	46,794	33,930	43,707	37,005
63. Total weight of moisture generated by combustion, lbs...............	50,004	48,240	56,151	64,449
64. Total weight of dry air heated for blast, lbs.........................	5,030,347	4,611,814	6,150,198	6,162,178
65. Total weight of moisture heated for blast, lbs......................	36,086	25,397	41,745	34,303
66. Total weight of gas through stack, lbs.	4,442,085	4,402,568	5,277,841	5,225,983
67. Total weight of blast, lbs.........	5,066,433	4,637,211	6,191,943	6,196,481
EFFICIENCY.				
68. Total heat absorbed by blast, B.T.U.	1,417,521,450	1,264,629,900	1,618,537,227	1,664,227,221
69. Total heat generated (corrected for sensible heat in gas above 62° F.), B.T.U....................	2,517,129,355	2,234,916,219	2,662,441,226	2,867,251,184
70. Efficiency, per cent...............	56.32	56.59	60.79	58.04
HEAT BALANCE.				
71. Total heat absorbed by blast, B.T.U.	1,417,521,450	1,264,629,900	1,618,537,227	1,664,227,221
72. Loss of heat to dry chimney gases, B.T.U.....................	487,848,410	484,272,391	584,433,439	582,916,975
73. Loss of heat to incomplete combustion, B.T.U...................	0	0	0	0
74. Loss of heat to moisture in air and gas, B.T.U..................	10,574,040	7,639,679	10,005,844	8,561,107
75. Loss of heat to moisture from hydrogen, B.T.U.................	63,693,595	61,407,590	71,689,666	82,439,938
76. Loss of heat to radiation, B.T.U.	261,638,640	199,752,739	269,136,000	270,352,879
77. Loss of heat unaccounted for, due to stove changes, etc., B.T.U...	275,853,220	217.213,920	108,639,050	258,753,064
78. Total heat absorbed by blast, per cent.	56.32	56.59	60.79	58.04
79. Loss of heat to dry chimney gases, per cent..........................	19.38	21.67	21.95	20.33
80. Loss of heat to incomplete combustion, per cent...............	0	0	0	0
81. Loss of heat to moisture in air and gas, per cent...............	0.42	0.34	0.38	0.30
82. Loss of heat to moisture from hydrogen, per cent..............	2.53	2.75	2.69	2.88
83. Loss of heat to radiation, per cent.	10.39	8.94	10.11	9.43
84. Loss of heat unaccounted for, due to stove changes, etc., per cent.	10.96	9.72	4.08	9.02
THERMAL OUTPUT.				
85. Total elapsed time for test from time stove was taken off furnace at start to end of test, hours	136.100	103.908	140.000	140.633
86. Average B.T.U. absorbed by blast per hour while stove was on furnace	39,627,672	46,587,950	46,311,403	47,440,913
87. Average B.T.U. absorbed by blast per hour for elapsed time of test	10,415,294	12,170,669	11,560,980	11,833,831
FUEL GAS ANALYSIS.				
88. CO_2, per cent. of volume..........	13.31	13.15	13.12	11.94
89 CO, per cent. of volume...........	25.22	24.54	23.38	24.84
90. O_2, per cent. of volume............	.28	.38	.46	.52
91. H_2, per cent. of volume............	3.91	4.11	3.88	4.45
92. N_2, per cent. of volume............	57.28	57.82	59.16	59.25

STACK GAS ANALYSIS.				
93. Stack No. 1, CO_2, per cent. of volume	19.91	17.76	18.16	18.15
94. Stack No. 1, CO, per cent. of volume	Nil	Nil	Nil	Nil
95. Stack No. 1, O_2, per cent. of volume	3.99	5.67	5.18	4.70
96. Stack No. 1, H_2, per cent. of volume	Nil	Nil	Nil	Nil
97. Stack No. 1, N_2, per cent. of volume	76.08	76.57	76.66	77.15
98. Stack No. 2, CO_2, per cent. of volume			16.95	
99. Stack No. 2, CO, per cent. of volume			Nil	
100. Stack No. 2, O_2, per cent. of volume			5.72	
101. Stack No. 2, H_2, per cent. of volume			Nil	
102. Stack No. 2, N_2, per cent. of volume			77.33	
103. Stack No. 3, CO_2, per cent. of volume	19.92	17.50	17.88	18.01
104. Stack No. 3, CO, per cent. of volume	Nil	Nil	Nil	Nil
105. Stack No. 3, O_2, per cent. of volume	3.91	5.63	5.14	5.17
106. Stack No. 3, H_2, per cent. of volume	Nil	Nil	Nil	Nil
107. Stack No. 3, N_2, per cent. of volume	76.17	76.87	76.98	76.82
AVERAGE STACK ANALYSIS.				
108. CO_2, per cent. of volume	19.92	17.63	17.66	18.08
109. CO, per cent. of volume	Nil	Nil	Nil	Nil
110. O_2, per cent. of volume	3.95	5.65	5.34	4.93
111. H_2, per cent. of volume	Nil	Nil	Nil	Nil
112. N_2, per cent. of volume	76.13	76.62	77.00	76.99

TABLE 2—TEMPERATURE IN COMBUSTION CHAMBER.

Time.	Location.	Temperature, Degrees F.
0 minutes	75′ from top	2,175
10 minutes	65′ from top	2,225
20 minutes	55′ from top	2,121
30 minutes	45′ from top	2,045
40 minutes	35′ from top	2,050
50 minutes	25′ from top	1,951
60 minutes	15′ from top	1,894
70 minutes	6′ from top	1,863

TABLE 3—ANALYSES OF FUEL GAS.

	Analysis—Per Cent. of Volume.					B.T.U. per Cu. Ft. at 62° F. and 30″ Hg.		Density of Dry Gas at 62° F. and 30″ Hg.
Test.	CO_2	O_2	CO	H_2	N_2	Gross.	Net.	Lbs. per Cu. Ft.
Test 1....	13.31	0.28	25.22	3.91	57.28	94.63	92.67	.076829
Test 2....	13.15	0.38	24.54	4.11	57.82	93.03	90.97	.076647
Test 3....	13.12	0.46	23.38	3.88	59.16	88.49	86.53	.076769
Test 4....	11.94	0.52	24.84	4.45	59.25	95.11	92.91	.075890

NOTE.

Test 1—Average of 36 samples taken at 4 hour intervals, from 8:30 A. M., Sept. 15, 1913, to 4:30 A. M., Sept. 21, 1913, inclusive.

Test 2—Average of 26 samples taken at 4 hour intervals, from 8:30 A. M., Oct. 28, 1913, to 12:30 P. M., Nov. 1, 1913, inclusive.

Test 3—Average of 35 samples taken at 4 hour intervals, from 11:30 A. M., Nov. 3, 1913, to 3:30 A. M., Nov. 9, 1913, inclusive.

Test 4—Average of 38 samples taken at 4 hour intervals, from 11:30 A. M., Nov. 10, 1913, to 4:30 A. M., Nov. 16, 1913, inclusive.

TABLE 4—ANALYSES OF STACK GAS.

	Stack No. 1 Per Cent. by Volume.				Stack No. 3 Per Cent. by Volume.			
Test.	CO_2	O_2	N_2	CO	CO_2	O_2	N_2	CO
Test 1.........	19.91	3.99	76.08	Nil	19.92	3.91	76.17	Nil
Test 2.........	17.76	5.67	76.57	Nil	17.50	5.62	76.87	Nil
Test 3.........	17.66	5.34	77.00	Nil	17.89	5.14	76.97	Nil
Test 3a........	16.95	5.72	77.33	Nil				
Test 4.........	18.14	4.70	74.09	Nil	18.01	4.90	76.81	Nil

NOTE.

Test 1—Average of 36 samples taken at 4 hour intervals, from 8:30 A. M., Sept. 15, 1913, to 4:30 A. M., Sept. 21, 1913, inclusive.

Test 2—Average of 26 samples taken at 4 hour intervals, from 8:30 A. M., Oct. 30, 1913, to 12:30 P. M., Nov. 1, 1913, inclusive.

Test 3—Average of 35 samples taken at 4 hour intervals, from 11:30 A. M., Nov. 3, 1913, to 3:30 A. M., Nov. 9, 1913, inclusive.

Test 3a—Average of 22 samples taken at 4 hour intervals, from 3:30 P. M., Nov. 6, 1913, to 3:30 A. M., Nov. 9, 1913, inclusive. (This analysis from Stack No. 2, per cent. by volume.)

Test 4—Average of 38 samples taken at 4 hour intervals, from 11:30 A. M., Nov. 10, 1913, to 4:30 A. M., Nov. 16, 1913, inclusive.

TABLE 5—GAS ANALYSIS IN CHECKERS.

Date.	Time of Sample.	Hole.	Distance from Shell of Stove.	Analysis. CO_2	O_2	N_2	CO	Density.
11/26/13	11:10 A. M.	D	6′	17.0	4.9	77.9	0.2	
	12:20 P. M.			16.9	1.6	81.1	0.4	
	Average			16.95	3.25	79.5	0.3	.081372
	11:10 A. M.	E	6′	17.6	6.0	76.4	Nil	
	12:20 P. M.			17.0	7.0	76.0	Nil	
	Average			17.3	6.5	76.2	Nil	.081864
	11:10 A. M.	F	6′	16.8	7.2	76.0	Nil	
	12:20 P. M.			13.2	7.6	....	Nil	
	Average			16.8	7.4	76.0	Nil	.081724
	11:10 A. M.	Stack No. 3		17.0	7.0	76.0	Nil	
	12:20 P. M.			16.8	6.8	76.4	Nil	
	Average			16.9	6.9	76.2	Nil	.081735
12/1/13	10:30 A. M. 1:30 P. M.	Stack No. 1		18.4	6.0	75.6	Nil	.082283
	10:30 A. M. 1:30 P. M.	Stack No. 3		19.0	5.4	75.6	Nil	.083319
	3:00 P. M.	E	3′ 9″	22.0	3.6	74.4	Nil	.083572
	3:00 P. M.	H		21.0	4.0	75.0	Nil	.083185
	3:00 P. M.	E	7′ 9″	20.8	2.8	76.4	Nil	.082973
	3:00 P. M.	H		12.4	2.4	85.2	Nil	.079334
	3:00 P. M.	H	11′ 9″	22.8	0.6	71.2	Nil	.079614

TABLE 6—GAS ANALYSIS AT VARIOUS POINTS IN THE STOVE.

Hole.	Distance from Inner Wall.	Distance from Outer Wall.	Time.	Gas in Stove Per Cent. by Volume. CO_2	CO	H_2	O_2	N_2	Per Cent. Complete Combustion.	Fuel Gas Analysis Per Cent. by Volume. CO	H_2	CO_2	N_2
Burner	1′		10:10 A.	19.9	4.0	1.7	0.3	74.1	80.4	24.5	4.5	14.0	57.0
Burner		1′	11:00 A.	18.3	4.5	1.1	0.4	75.7	80.5	24.5	4.5	14.0	57.0
A	1′		10:10 A.	12.7	8.6	2.3	1.2	75.2	62.8	25.1	4.2	14.3	56.4
A		1′	10:30 A.	16.4	6.0	2.2	0.5	74.9	72.0	25.1	4.2	14.3	56.4
B	1′		10:40 A.	17.1	4.3	1.7	0.8	76.1	79.6	25.3	4.1	13.5	57.1
B		1′	11:00 A.	18.7	2.1	1.0	0.8	77.4	89.5	25.3	4.1	13.5	57.1
C	1′		10:55 A.	20.9	1.1	0.3	0.5	77.2	95.3	25.4	3.9	14.5	56.2
C		1′	11:15 A.	21.6	2.0	0.0	0.3	76.1	93.0	25.4	3.9	14.5	56.2
D		1′	9:25 A.	20.1	0.0	0.0	0.9	79.0	100.0	25.4	3.9	14.5	56.2
D	1′		9:45 A.	21.5	0.0	0.0	0.9	77.6	100.0	25.4	3.9	14.5	56.2
E		1′	2:20 P.	22.9	0.0	0.0	0.9	76.2	100.0	25.3	4.1	13.5	57.1
E	1′		2:00 P.	22.9	0.0	0.0	0.9	76.1	100.0	25.3	4.1	13.5	57.1

TABLE 7—DUST AND MOISTURE IN BLAST FURNACE GAS.
Grains per cu. ft. at 62° F. and 30″ Hg.

	Test 1	Test 2	Test 3	Test 4
Moisture	7.413	5.6885	5.5469	4.8614
Dust	.07186	.0811	.1385	.1876

THE USE OF WASHED GAS IN BLAST FURNACE STOVES.

The use of clean gas in blast furnace stoves is absolutely necessary if we wish to secure the most efficient results.

With clean gas, smaller checker openings can be used and greater heating surface obtained, we do not blow so much dust through hot-blast valves, pipes, tuyeres, etc., and they are not cut so badly, nor is nearly the amount of costly repairs required on this equipment or on the linings of the stoves themselves. We can also get perfect combustion with clean gas and have a uniform heat at our command at all times for the blast furnace. These results cannot be obtained with dirty gas, due to the plugging up of checker openings and the filling up of the stove wells with clinker, which is very difficult to remove, and which injures the walls of the combustion chambers and the efficiency of the heat absorption of the entire brickwork of the stove.

The usual practice for a plant with several blast furnaces is to use an efficient dust-catcher on each furnace, and at times additional auxiliary dry dust catchers or dry cleaners so as to catch as much as possible of the heavy material sent over with the blast furnace gases,

as this material is valuable and can more easily be taken care of in the dry state. From here the gas is collected in one central dirty gas main, and from this main conducted to the washers, or it can be used directly as dirty gas in emergencies. This arrangement tends to equalize the variations in the composition and amount of gas given off by the different furnaces, and better and more regular results are obtained.

The most important point in all gas-washing processes is to cool the gas sufficiently to precipitate the moisture and eliminate it from the gas. The ideal condition for blast furnace stoves or boilers would be a hot gas containing neither dirt nor moisture, but very good results are obtained with a dirt content in the gas of .15 of a grain per cubic foot and a temperature of 70°, which corresponds to a moisture content of 8 grains per cubic foot at saturation.

Anyone wishing to study the different gas-cleaning processes further is referred to Mr. Forbes' paper, read before the American Institute of Mining Engineers, October, 1913, and Mr. A. N. Diehl's paper, read before the same society, in February, 1914.

POWER PLANTS IN CONNECTION WITH BLAST FURNACES.

Of late, much greater thought and study is being given to this part of the subject than heretofore, as we fully realize that the steam practice in blast furnace plants is not comparable with that of modern central power stations.

Most of the large blast furnace plants in this country have been gradually increased in capacity by adding one or two additional furnaces from time to time, as additional product was required. In most cases this has resulted in separate boiler plants, blowing plants, etc., being installed for each set of furnaces added, which, of course, has not tended towards lower operating costs or decreased fuel economy. It has always been customary,

however, in these cases, to connect the gas and steam lines from all the various units, which has helped the efficiency to some extent.

It is very important to concentrate power plants as much as possible to effect savings in operating cost, as well as in fuel.

If boilers are used, the boiler plants should be as few as possible, and consist of large units, so as to keep at a minimum the number of units required for large powers, as the maximum concentration of power is always an advantage to effect savings in costs. The steam pressure used should be 175 pounds or more, and the plant should have all modern economical appliances, such as superheaters, feed-water heaters, and, when necessary, water-treating plants, fuel economizers, etc. Higher boiler efficiencies can be attained by careful study of these various details, as well as the more efficient burning of gas on gas-fired boilers, the adoption of time firing of coal as practiced on marine coal-fired boilers, or by the use of powdered coal. By attention to such details it should be possible to raise the average boiler efficiency well up towards 80 per cent. It is preferable to have a separate boiler-house in a blast furnace plant on account of the dust, dirt and gas unavoidably connected with plants of this kind.

In making a selection of steam blowing engines, turbo blowers, or gas blowing engines, as well as steam turbines or gas engines for power purposes, the local conditions regarding the value of fuel must be studied, as well as the considerations as to whether there is an outlet for excess power in connection with other departments, such as steel works or other industrial plants. We can expect to obtain approximately 22 per cent. thermal efficiency from the gas engine, and with additional modern improvements such as those which make use of the heat usually wasted in the cooling water and in the exhaust gases, these efficiencies will no doubt be still further increased when their use becomes general.

Modern steam blowing engines or turbo blowers with the installation of modern boilers, from all the information I have been able to obtain, cannot show over 12 per cent. thermal efficiency.

The turbines used for power purposes may do slightly better than this, on account of the practicability of their installation in very large units.

Many claims are made for the turbo blower on account of its delivering a more uniform supply of air, effecting a lower coke consumption, greater production, etc. These claims look very questionable as it takes a definite amount of oxygen to consume a definite amount of carbon, no matter how it is supplied; therefore, in choosing between turbo blowers and gas blowers, it looks as if the efficiency and cost of the different kinds of prime movers, their operating cost and upkeep, and the fuel value in the district, alone should be considered.

Considering fuel costs, cost of installation, etc., the blast furnace gas engine would be the choice in most modern blast furnace installations, except where the value of fuel is very low, or where there is no outlet for excess power.

THE USE OF DRY BLAST FOR BLAST FURNACES.

Under the heading of air supplied to blast furnaces, we have considered the importance of eliminating moisture, and have also mentioned the Gayley dry blast process. This process helps greatly to more uniform and successful blast furnace practice, as in addition to producing uniform moisture content in the air blast, it gives the furnace a uniform supply of oxygen by weight, and I am satisfied that Mr. Gayley's original claim, "The claim I personally make for the process is that with an increase in output of 10 per cent. the saving in fuel per ton of iron will be reduced 10 per cent., and I consider this conservative," has been borne out by later experience with the plants using dry blast.

I am aware that there have been instances in which

the results from these plants have been disappointing, as much greater savings were expected than Mr. Gayley originally claimed; but in a matter of this kind the results in one particular case should not be considered, but rather the average results of all installations accepted as decisive, and I know that, on the average, Mr. Gayley's claim has been fully borne out.

There are very special cases where a furnace is on very low coke per ton of iron, say from 1,600 to 1,800 pounds, when conditions happen to be most favorable, but this is by no means an average condition. In such cases we could not look for the entire saving, but even on that basis we would gain much by the increased regularity due to dry blast. It must be remembered that the quantity of carbon in a blast furnace must always be sufficient to maintain a reducing action in the gas produced by oxidation of fuel at the tuyeres.

I would like to go into this process more in detail, but will call your attention in this connection to some ancient history in the use of hot blast, which, in my judgment, is also applicable to dry blast, showing that the local conditions must be taken into consideration.

When hot blast was first introduced in Scotland by Nielson, the economy effected was very great, and it spread rapidly through Scotland. When its advantages became known, installations were made in other countries, but in some cases the saving in coke consumption, increased production, etc., were not so great, due to the fact that the local furnace practice did not offer the same comparison as did the Scottish; but in all instances its introduction was accompanied by increased production, and with marked economy in fuel.

FUTURE DEVELOPMENTS IN BLAST FURNACE PRACTICE.

The application of the sciences of Physics and Chemistry to blast furnace practice has made a wonderful transformation in the manufacture of iron. We have

reviewed many of the important details of this subject. The question now is what can be expected in the way of future advancement.

With the exception of coke and some additional treatment required for ores, the raw materials will remain practically the same. By-product coke, on account of its manufacture allowing the mixture of various kinds of coal, will in the future replace all beehive coke operations, since it permits the use of large quantities of coals which alone are not suitable for beehive coke manufacture. Coke oven gas, tar, ammonium sulphate and benzol will be recovered. More use will be made of blast furnace cinder, which will be commercialized to a much greater extent, not only for cement, ballast, and road material, but also for making a good quality of building and paving brick, which has already been done very successfully.

The location of a plant should be chosen, not only with reference to the market for its principal product, but with careful consideration of the outlet for its almost equally important by-products.

In many instances so great has been the advancement in appliances for the economical handling of materials around blast furnace plants that it is questionable if this can be carried any further and show a profit on the investment.

Blast furnace plants having a number of furnaces can effect economies by the concentration of their power plants to as great an extent as possible.

Where boilers are used, large units should be installed, and in as few boiler-houses as possible. The same applies to both steam or gas blowing engines or turbo blowers, power-houses, pump-houses, etc. Wherever possible, all power and pump stations should be combined under one roof, to reduce the operating expense; the boiler-houses, as before stated, being preferably located in a separate building.

In power stations the importance of combining the various thermal processes in series, and rejecting the

remaining heat at the lowest possible temperature, is fully realized. This is also true in the use of blast furnace gas for other purposes, such as in stoves, etc., all of which economies tend not only to lower the cost of production, but are also of great importance as an aid in the conservation of our national resources.

Regarding the fuel consumption of a blast furnace, when it has been reduced to approximately 2,000 pounds per ton of iron, I question under some conditions whether it is desirable to endeavor to bring it very much lower, as our greatest economies to be made in the future are from the economical use of the waste gases from blast furnaces, especially when connected with large steel works.

We will secure these thermal economies by:

(1) Increased efficiency of hot-blast stoves. This may be obtained by reducing the present losses due to radiation; the use of larger checker surfaces exposed to the passage of gases; more efficient burning of gas in stoves, and by the utilization of the waste heat from stove stacks for either preheating the blast before its entry into the stove or preheating the air for mixing with the gas for combustion.

(2) Increased efficiency from blast furnace power plants by the use of gas engines or more modern steam equipment, and, when gas engines are used, increased efficiency will result from saving the heat of the waste gases and cooling water.

(3) Increased efficiency thermally by utilizing the sensible heat at present lost in the molten iron and slag. This loss is quite serious, as may be noted by referring to the heat distribution account, page 38, where "Heat in Pig Iron" amounts to 5.39 per cent., and "Heat in Slag" amounts to 6.25 per cent. of the total heat derived from the coke of the burden.

These losses have already been studied, and efforts are constantly being made to decrease losses in these directions, much having already been done to effect savings. The latest saving has been effected by utilizing the

heat from slag to indirectly generate steam for low-pressure turbines. Savings will eventually be made in the case of the molten iron.

The maximum utilization of all the by-products in connection with the manufacture of iron is the goal towards which we all must strive for the future advancement of the art.

In connection with this paper I wish to acknowledge my indebtedness to Paul D. Wright, Assistant to Superintendent of the Edgar Thomson Furnaces, and A. F. T. Wolff, Steam Expert of the Edgar Thomson Works, under whose direction tests were carried out; also to the chemists and members of our students' course who assisted in obtaining the data. (Applause.)

President Gary: We shall now have a discussion of this paper by Mr. Ambrose N. Diehl, Superintendent of the Duquesne Furnaces of the Carnegie Steel Company.

BLAST FURNACE ADVANCEMENT

Discussion by Ambrose N. Diehl

Superintendent Blast Furnaces, Carnegie Steel Company, Duquesne, Pa.

We have heard a very able paper on the probable trend of Blast Furnace improvements. Mr. Maccoun has taken us from the raw materials to the finished product, suggesting various improvements to be made in the progressive steps in the production of pig iron. I thoroughly agree with him in his outline for future furnace advancement, but desire to raise the question, are we not, after all, only arriving at the same Operating Practice which the then modern plants had about fifteen to eighteen years ago?

The desire in the manufacture of pig iron is—

First: To produce the quality best suited for future use.

Second: To produce it as cheaply as possible.

Third: To produce the greatest quantity possible while fulfilling the first two conditions.

An average for three years shows on the best representative present furnace, with high heats, conditioned material, and modern equipment, a daily tonnage of 529 tons, with a coke consumption of 1,925 pounds per ton. This furnace has a limestone consumption of between 800 and 900 pounds per ton, and is producing iron running about .04 sulphur. In a few instances, under good conditions, cokes have been shown in individual cases between 1,600 and 1,700 pounds per ton. The latter practice to which I referred is obtained through the use of coke running about .5 sulphur and between 91 and 92 fixed carbon, together with a coarse washed ore and sinter. The requirements are about 600 to 700 pounds of limestone per ton of metal. An open burden such as this is capable of carrying extremely high heat and serves to illustrate possibilities with properly conditioned material.

Fifteen years ago there were few so-called modern plants with which the present practice could be compared. The Duquesne Furnaces of the Carnegie Steel Company might be termed pioneers in this development, and I wish to insert, for comparison, Chart A, showing the weekly practice of these furnaces for the years 1897-1898 and 1899. Also Chart B, which shows a comparison of the Duquesne Basic Furnace No. 4 during the same period, with a furnace having the best practice shown over the years 1912, 1913 and 1914. It will be seen that, when due allowance in tonnage and coke is made for the 72° of additional hot blast that the practice is about the same. Table A shows average yearly practice.

During the fore-mentioned three-year period, a comparison of averages will show as follows:

		Coke.	Analyses.		
	Tonnage	Lbs.	Sil.	Sul.	Heat
Three Duquesne Bessemer Fces.	502	1,979	1.17	.026	948°
One " Basic "	524	1,943	.71	.041	1,013°
Compared Furnace...........	529.3	1,925	——	——	1,085°

Many hand-filled furnaces, with the same material as used at Duquesne, and during the same period, showed similar results as far as coke and analyses are concerned, but a lower tonnage, due to inadequate filling and power equipment.

In the Pittsburgh and Valley districts the furnace practice was carried out by using Old Range Lake Superior ores like Pioneer, Vermillion and Norrie, and also about 35% of high-grade Mesaba, 72-hour Connellsville Basin coke and a good grade of limestone. With the advent of higher percentages of physical fine Mesabas, economies in the manufacture of coke, and the entrance of other coal fields which lowered the efficiency, physical strength and structure of the coke, the practice changed. Furnaces became more irregular, and slips, with excessive losses and high coke consumption, resulted. Many variations in ash analyses resulted from the necessary consumption of the products from a greater number of small coke plants, each with its own local method of manu-

TABLE A

Average Practice at Duquesne Blast Furnaces.
For Years 1897, 1898 and 1899.

	1897—6¼ Months.		1898=12 Months.		1899—12 Months.	
	Bessemer.	Basic.	Bessemer.	Basic.	Bessemer.	Basic.
Daily Product	477	438	515	532	514	565
Coke per Ton Iron	1,940	2,016	1,939	1,842	2,059	2,001
Silicon in Iron	1.11	1.00	1.17	.53	1.24	.59
Sulphur in Iron	.023	.034	.025	.042	.029	.048
Ratio Coke to Ore	2.027	1.934	2.137	2.210	1.988	2.105
Percentage Mesaba Ore Used	37.48	36.08	36.05	36.57	33.13	39.83
Percentage Flue Dust Made	4.1	5.3	5.5	4.5	4.8	4.0
Flue Dust per Day—T	35	39	52	44	45	42
Flue Dust per Month—T	1,069	1,398	1,576	1,282	1,362	1,288
Theoretical Slag Vol.	1,108	1,157	Not Calculated.		Not Calculated.	
Silica in Slag	33.03	32.96	33.53	32.16	33.75	33.11
Alumina in Slag	14.01	14.37	14.46	14.56	15.00	14.34
Cubic Feet Air per Minute	40,352	37,244	47,280	45,827	53,765	54,423
Cubic Feet Air per Ton Iron	118,096	121,044	Not Calculated.		146,566	134,352
Cubic Feet Air per Pound Coke	60.7	60.0	Not Calculated.		74.0	67.3
Silica in Ores	5.8	6.2	Not Calculated.		Not Calculated.	
Heat in Blast	925	950	976	1,038	943	1,025
Percentage Limestone	24.5	24.3	Not Calculated.		22.4	21.5

Three furnaces, Nos. 1, 2 and 3, working Bessemer.
One furnace, No. 4, working Basic.

CHART A

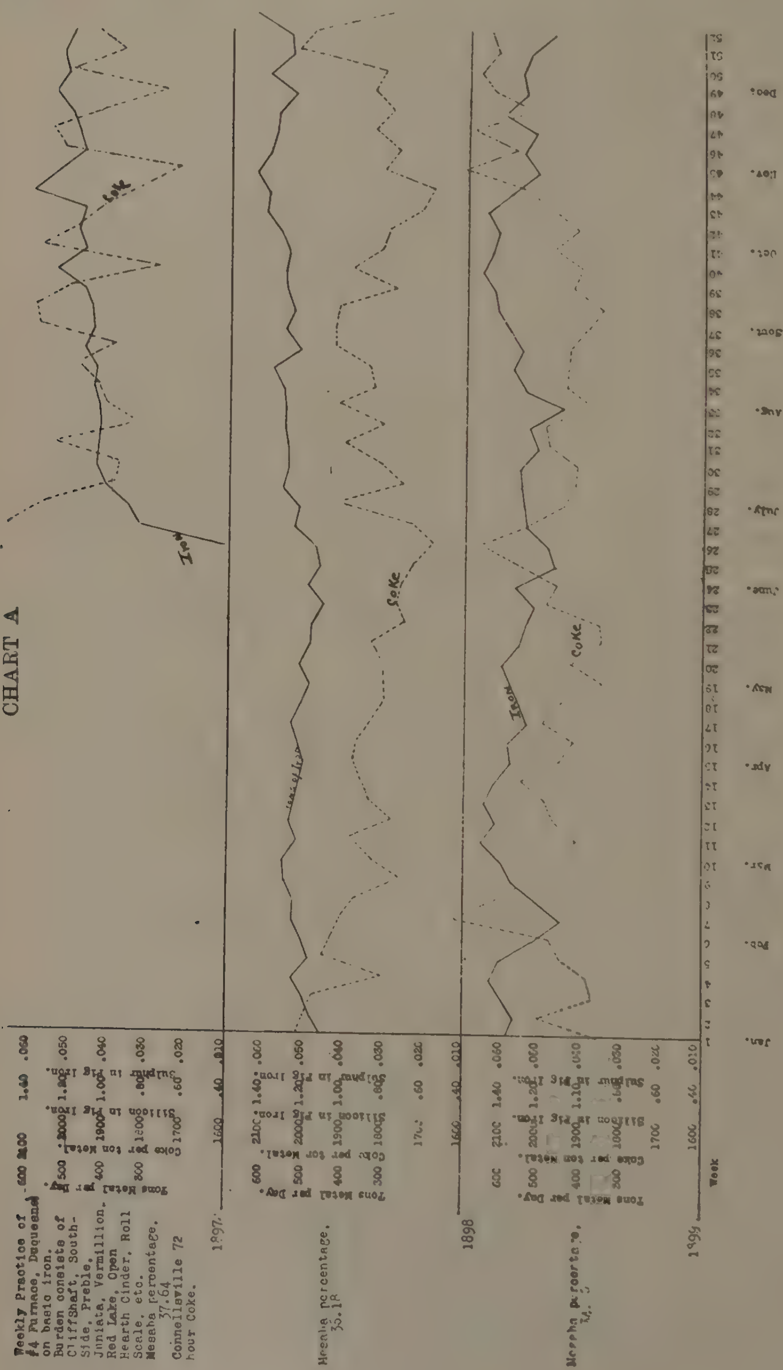
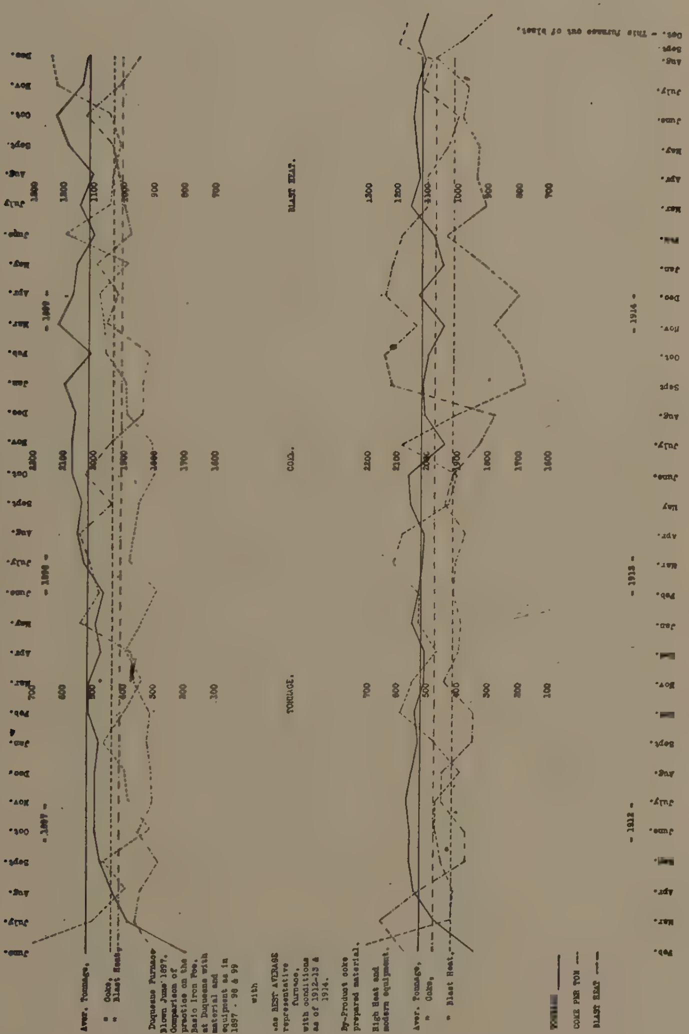

Weekly Practice of #4 Furnace, Duquesne on basic iron.
Burden consists of Cliff Shaft, South-Side, Preble, Juniata, Vermillion, Red Lake, Open Hearth Cinder, Roll Scale, etc.
Mesaba percentage, 37.64
Connellsville 72 hour Coke.
1897
1898
1899
Tons Metal per Day.
Coke per ton Metal.
Silicon in Pig Iron.
Sulphur in Pig Iron.
Week
Coke
Iron

CHART B



facture, and therefore a new practice had to be evolved to correspond with the other conditions which had arisen.

Progress in economies and efficiencies of operation did not stop with ore and coke managements, but the germ seemed to enter the steel consumer as well. Specifications, chemical and physical, became more rigid and all sorts of tests were advanced. The result was an extreme pressure on the blast furnace from two convergent sides, namely, to make better and more economical product with a worse material. This was met by furnace managers straining every effort to offset the new conditions by a careful diagnosis of the difficulties to be overcome.

Fortunately the combustion of carbon to monoxide or dioxide remained the same as ever. Alumina, acting either as a base or an acid, still performed its same old functions. Iron oxide was still reduced by CO or solid carbon. These fundamentals remained unchanged irrespective of commercial relations.

Regularity and Uniformity.

It became evident that the principal problem was to secure regularity and uniformity.

To attain this uniformity and regularity new plants have been erected, or old plants remodelled, in which are supposed to be embodied the good results of the older ones, and these alterations have resulted, in most cases, in a mechanical equipment which was far superior to the parent plants. These equipments, although very expensive, have become necessary for the regularity which has become so paramount.

Uniformity of material entering the furnace is of first importance. By this is meant the proper distribution on the main bell and in the furnace, and also the relation of the stock to the air distribution at the tuyeres, and the gas offtakes on top. If the material is coarse it is evident that the gases will have a tendency to penetrate all parts of the mixture; while if it is fine and packs along the walls, this condition will be greatly hindered, and the

gases will come up through the center or through some other easy point of access. If the oxygen, burned to carbon monoxide in the hearth, channels through the stock at any point, it is evident that an irregularity working furnace will result, and that the gases will pass through with a high velocity and escape with high-top temperature, naturally resulting in excessive fuel and losses. Fine material, which chokes up the interstices of the column of material, therefore, is the main element which interferes with the uniform distribution of blast and gas, causing scaffolding, channelling and the resulting evils attending these conditions. If the gas rises uniformly through the stock, over the entire area of the furnace, the velocity is decreased and the contact increased so that losses decrease in the same proportion. The distribution of stock, therefore, should be such as to present an even resistance to the uprising gas. These conditions all lead back to the essentials of our practice fifteen years ago, that is, a firm, clean coke of good cell structure, and a coarse and granular mixture.

Formerly a by-product coke was inferior to a coke produced in bee-hive ovens, but conditions have reversed since a lot of research work in the by-product field has shown that a modern blast furnace oven can by its construction and other facilities make a more uniform structure, uniform ash and uniform size, as well as a cleaner coke than the bee-hive construction.

Mesaba ores are being graded and mixed in ten-car lots based on silica, phosphorus and manganese content, so that the regularity from an analyses standpoint is becoming more pronounced each year. In some cases the ore is washed, leaving a very good product for blast furnace use. Clinkering of ore should open up an enormous field and make available many fine deposits which are causing a lot of our operating troubles at present and will cause more in the future if they are not prepared. The average sieve test of ore does not show its actual physical condition.

Comparison of Dry-Sieved and Wet-Sieved Ore.

Attached is Table B and a number of graphic charts showing a comparison of ore dry-sieved through various mesh screens, as indicated in the report, with the same ore wet-sieved having all the fine particles which cling to the larger ones washed through to the classification screen on which they belong. This gives one a more accurate idea of the actual percentage of fine material in the burden, and should be used instead of dry-screening for determining the physical condition of the ore. The range shown is from 7% to 19% additional fines through the 100-mesh screen.

Other Improvements.

Limestone is mined in some cases instead of quarried, screened and washed. It is evident that a good stone so prepared with the very fine material and clays removed would be superior to any conditioning which limestone has yet received for blast furnace practice. The stone is sorted at the quarries and mixed on silica analysis. This is a proper move in the right direction and will aid enormously in practice betterments.

Flue dust is concentrated and briquetted for open hearth use or clinkered for blast furnaces. The product of these methods in many cases is in better physical shape than the original ore. Some plants are using successfully from 20 to 25 per cent. of this material in their charges, and doing greatly improved work, due to the tendency of opening the burden to allow easier passage of gases with their consequent greater efficiency of reduction.

Stoves are enlarged from 150,000 sq. ft. of heating surface to 250,000 sq. ft. per furnace, using washed gas and small checkers to get this additional surface. Such stoves will show 1,300° straight line heat.

It is seen that all this necessary development, with the addition of 200 to 300° of heat, is required to restore the operating practice to what it formerly was, as shown by the Duquesne statistics mentioned above.

TABLE B

WET SIEVE ANALYSIS OF ORES, 1914.

	Ore No. 1.		Ore No. 2.		Ore No. 3.		Ore No. 4.		Ore No. 5.		Ore No. 6.		Ore No. 7	
	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%
On 10 Mesh Screen,	202.5	40.50	203.0	40.60	208.5	41.70	262.5	52.50	311.5	62.30	325.5	65.10	251.5	48.30
20 " "	29.5	5.90	27.0	5.40	80.0	16.00	59.5	11.90	16.0	3.20	62.0	12.40	44.0	8.80
40 " "	69.0	13.80	42.0	8.40	51.0	10.20	47.5	9.50	17.5	3.50	27.0	5.40	35.5	7.10
60 " "	16.5	3.30	18.0	3.60	14.5	2.90	13.0	2.60	6.0	1.20	18.5	3.70	7.0	1.40
80 " "	29.0	5.80	22.0	4.40	16.5	3.30	14.0	2.80	10.0	2.00	7.0	1.40	10.0	2.00
100 " "	5.5	1.10	3.5	.70	4.0	.80	3.0	.60	2.0	.40	1.5	.30	2.5	.50
150 " "	28.5	5.70	35.0	7.00	16.5	3.30	12.0	2.40	19.5	3.90	7.5	1.50	20.5	4.10
200 " "	14.5	2.90	12.0	2.40	11.0	2.20	9.0	1.80	32.5	6.50	5.0	1.00	10.5	2.10
300 " "	12.0	2.40	11.5	2.30	2.5	.50	4.5	.90	8.0	1.69	3.5	.70	10.0	2.00
Thru 300 " "	93.0	18.60	126.0	25.20	95.5	19.10	75.0	15.00	77.0	15.40	42.5	8.50	118.5	23.70
Total Grammes,	500.0	100	500.0	100	500.0	100	500.0	100	500.0	100	500.0	100	500.0	100

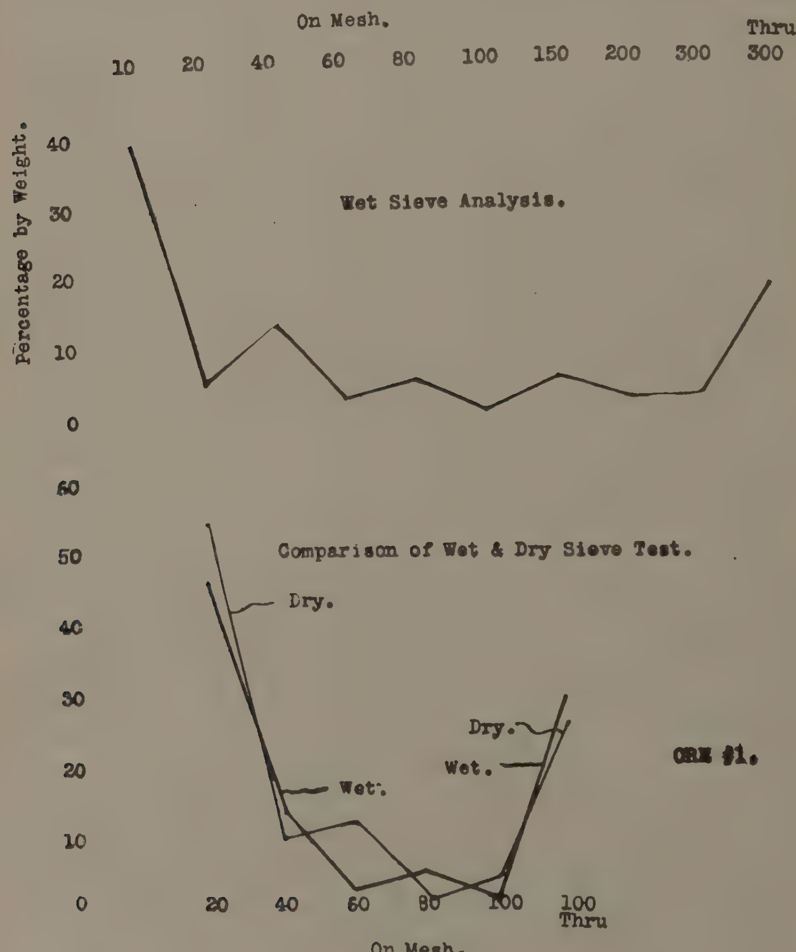
COMPARISON OF DRY AND WET ANALYSIS OF ORES.

	Ore No. 1.		Ore No. 2.		Ore No. 3.		Ore No. 4.		Ore No. 5.		Ore No. 6.		Ore No. 7	
	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.
On 20 Mesh Screen,	54.59	46.40	61.13	46.00	71.08	57.70	71.70	64.40	79.13	65.50	86.91	77.50	65.83	57.10
40 " "	10.36	13.80	10.08	8.40	6.92	10.20	7.54	9.50	3.36	3.50	4.48	5.40	10.05	7.10
60 " "	12.44	3.30	10.58	3.60	6.29	2.90	5.66	2.60	2.66	1.20	2.51	3.70	7.79	1.40
80 " "	1.70	5.80	1.44	4.40	1.25	3.30	1.26	2.80	.42	2.00	.36	1.40	1.01	2.00
100 " "	4.67	1.10	3.33	.70	2.51	.80	1.89	.60	1.12	.40	.90	.30	2.51	.50
Thru 100 " "	16.24	29.60	13.44	36.90	11.95	25.10	11.95	20.10	13.31	27.40	4.84	11.70	12.81	31.90
	100	100	100	100	100	100	100	100	100	100	100	100	100	100

DRY SIEVE ANALYSIS OF ORES.

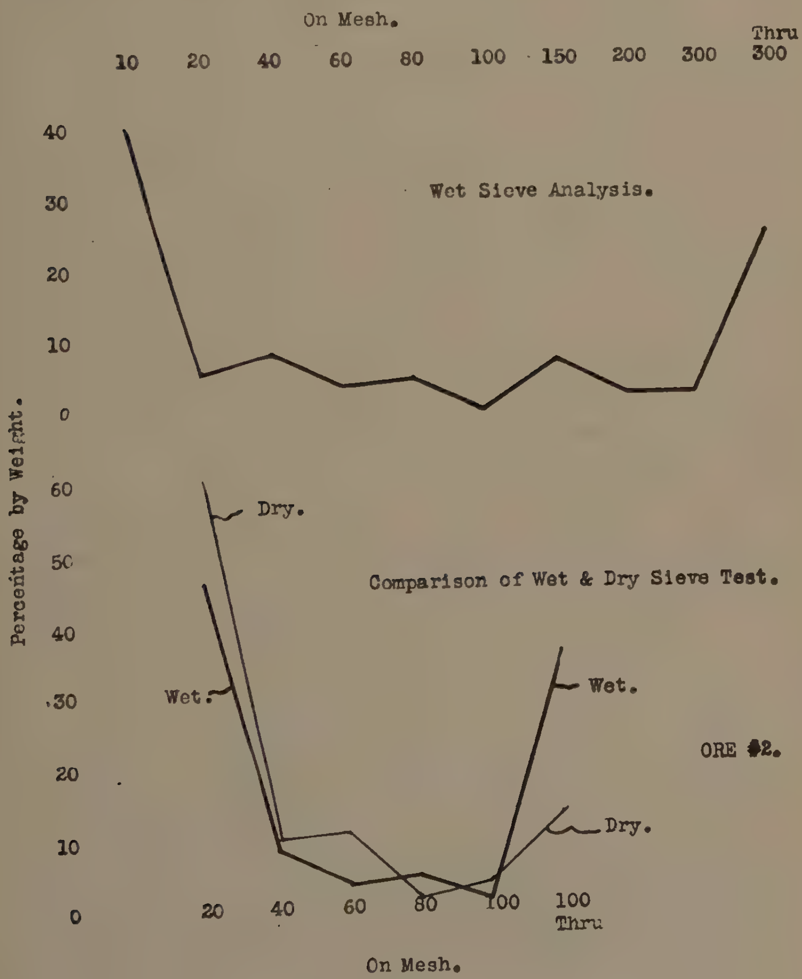
	½″ Mesh.	⅛″ Mesh.	20 Mesh.	40 Mesh.	60 Mesh.	80 Mesh.	100 Mesh.	Thru Mesh.
Ore No. 1	15.76	24.50	14.33	10.36	12.44	1.70	4.67	16.23
" " 2	15.76	28.48	16.89	10.08	10.58	1.44	3.33	13.44
" " 3	17.61	34.60	18.87	6.92	6.29	1.25	2.51	11.95
" " 4	15.09	36.48	20.13	7.54	5.66	1.26	1.89	11.95
" " 5	38.52	29.83	10.78	3.36	2.66	.42	1.12	13.31
" " 6	23.65	45.34	17.92	4.48	2.51	.36	.90	4.84
" " 7	16.08	28.14	21.61	10.05	7.79	1.01	2.51	12.81

If a burden is fine the furnace will not take high heat and the intensity of blast is therefore limited, while if the burden is coarse, and of open structure, it will take all the heat which can be possibly given with the resulting additional economies of at least 50 pounds of coke per 100° of temperature applied, up to a reasonable operating point. It has been the practice in some plants to run a very acid slag, which ofttimes allows the use of much higher heat without difficulty, with the same materials,

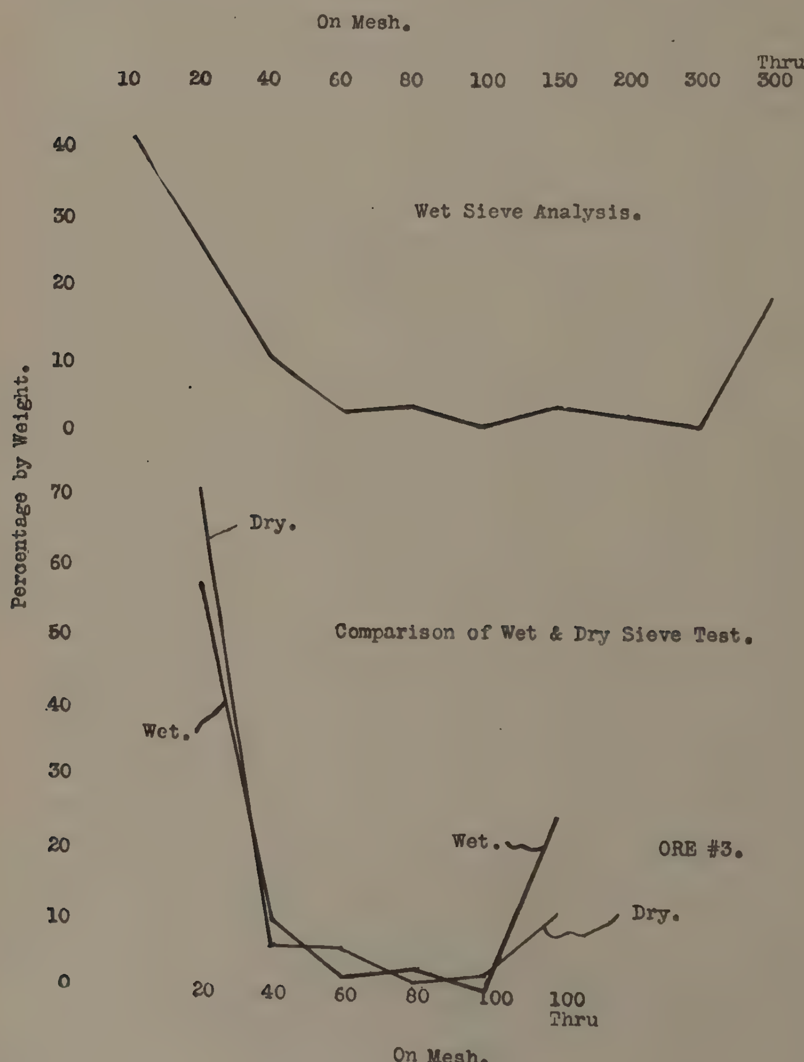


than a slag more basic. This, however, is considered by many plants, especially those where a rich and thoroughly reduced iron is essential, to be bad practice, as the iron is not so "rich" if the hearth temperature is indicated by the silicon content instead of by the temperature of a more infusible basic slag.

Should the burden be coarse and open, a more basic slag can be carried, better iron produced, and the furnace

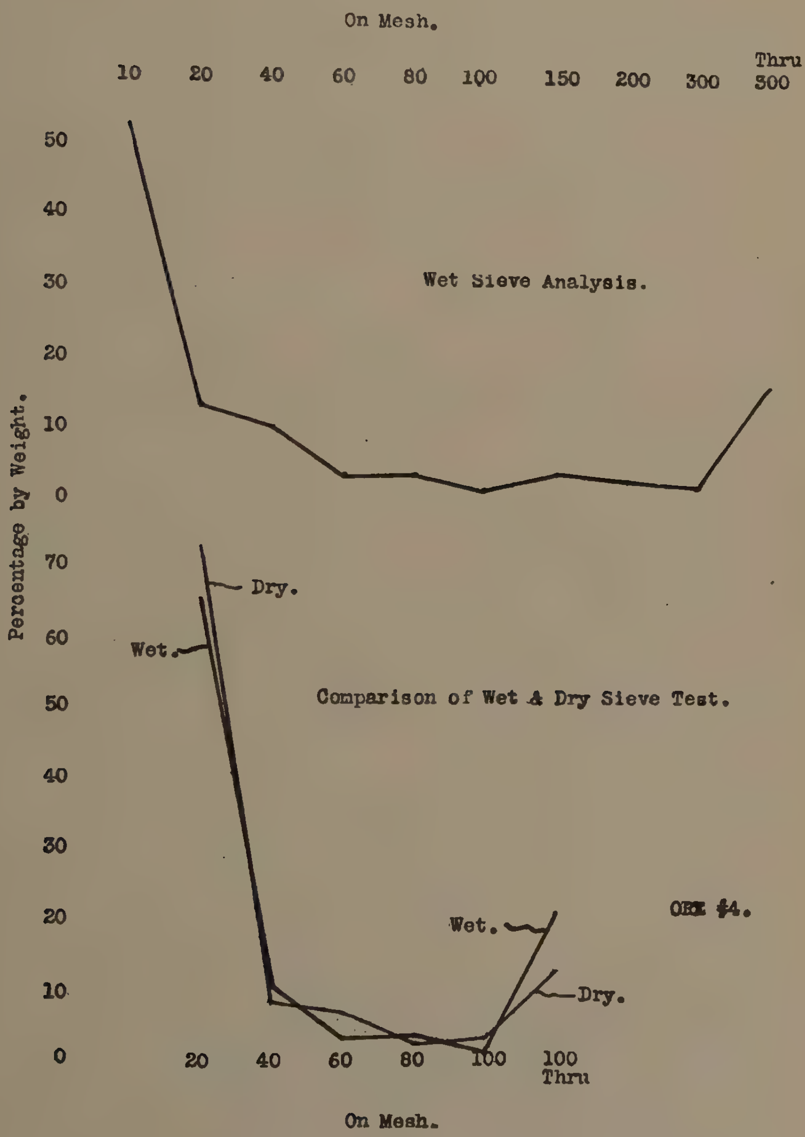


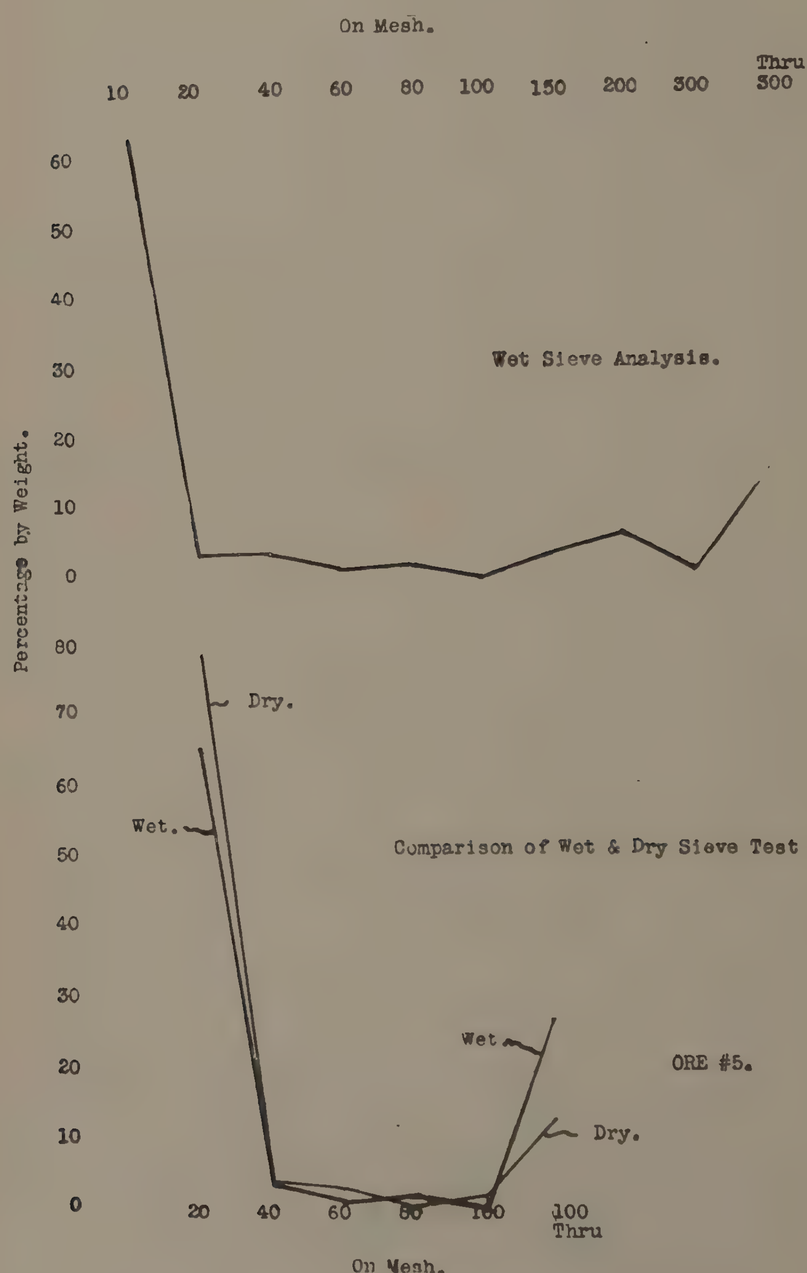
take higher blast temperatures without the danger of impairing the product. German practice with regard to high heats bears out this point for this very reason, and they have been able to develop more rapidly than we in this phase of the practice. This has been the basis of the wonderful strides they have lately made in practice, but

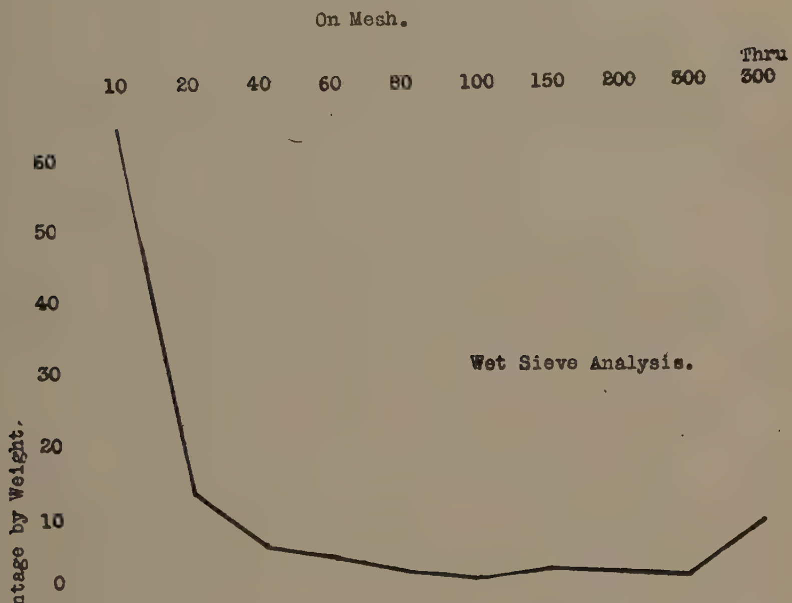


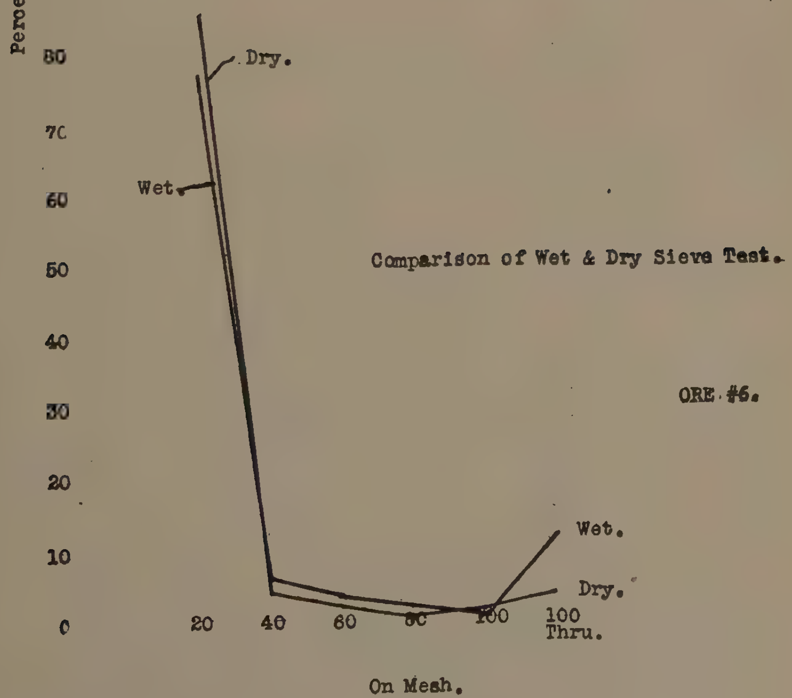
is not at all to our discredit, and make a comparison of American and German practices rather unfair.

While the present actual Operating Practice is no better than that shown, yet the development and saving in

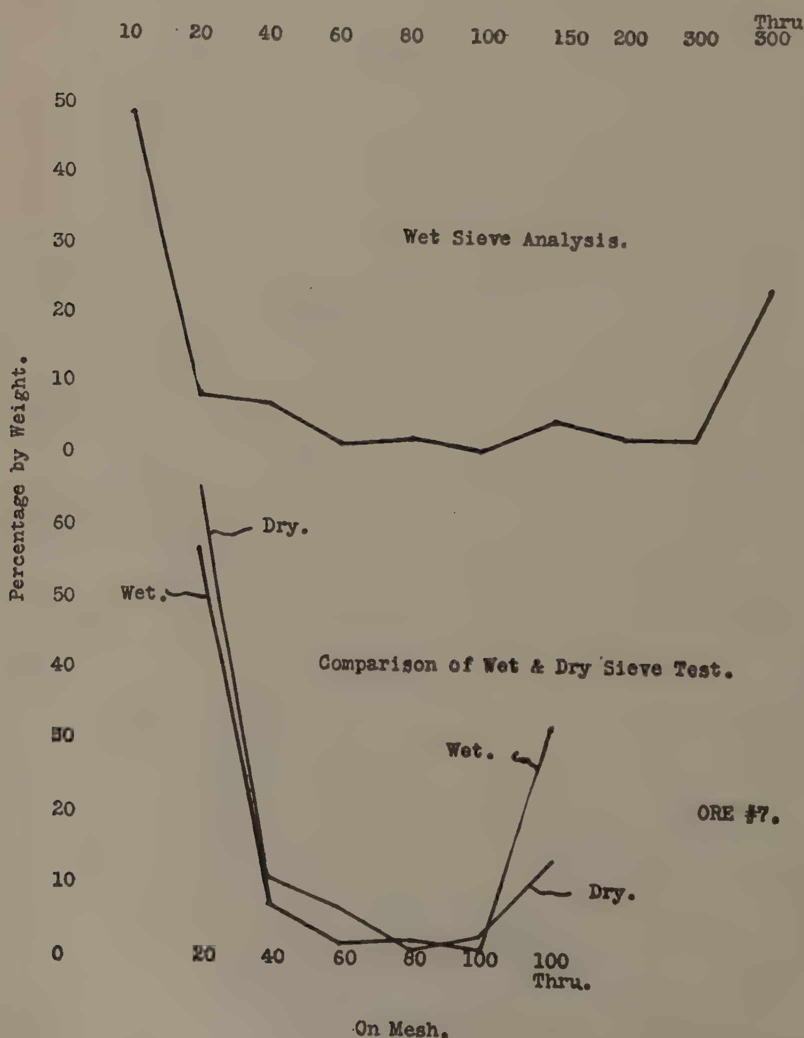


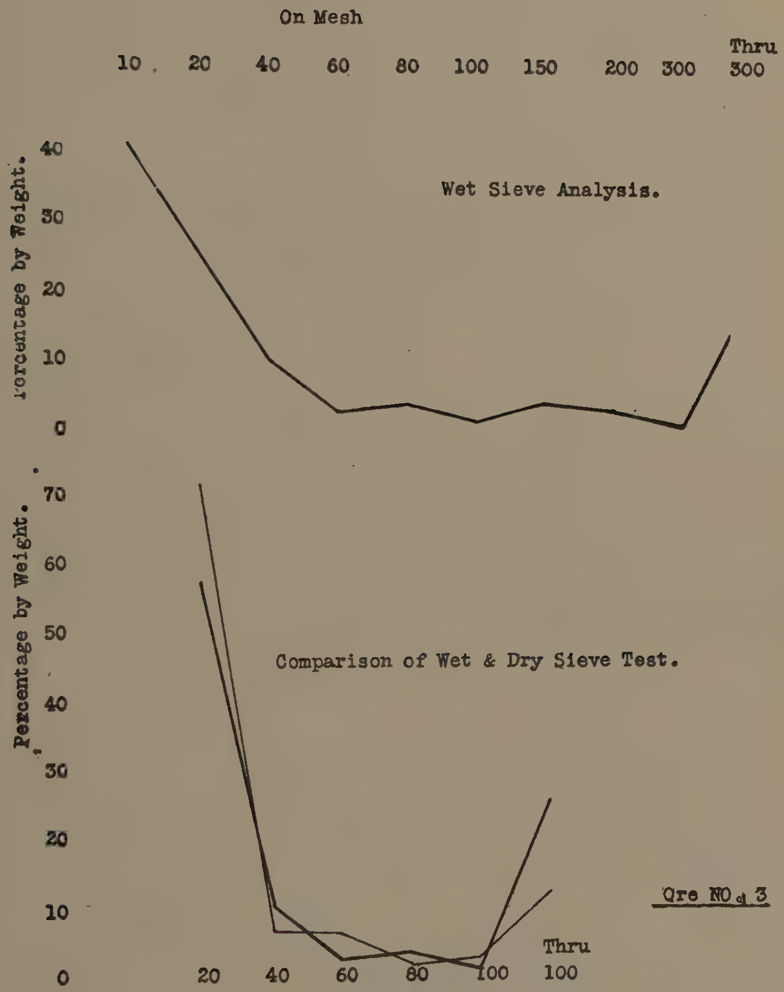

On Mesh.
10
20
40
60
80
100
150
200
300
Thru 300
Percentage by Weight.
60
50
40
30
20
10
0
Wet Sieve Analysis.
80
70
60
50
40
30
20
10
0
Dry.
Wet.
Comparison of Wet & Dry Sieve Test
Wet
ORE #5.
Dry.
20
40
60
80
100
100 Thru
On Mesh.

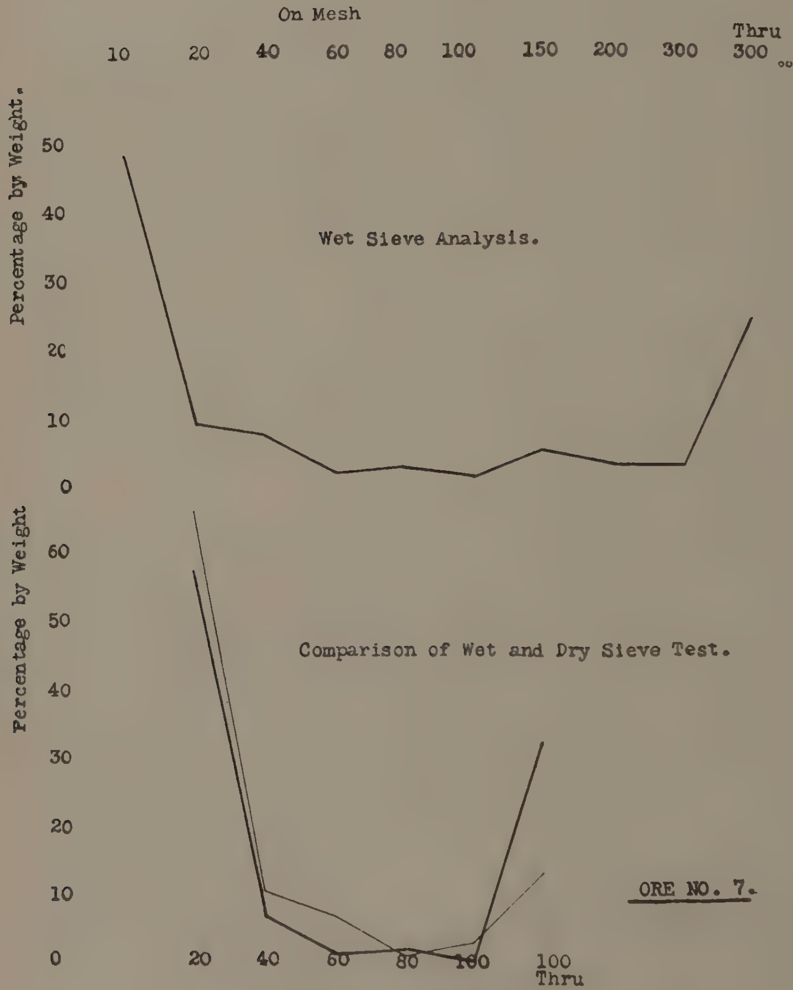

On Mesh.
10
20
40
60
80
100
150
200
300
Thru 300
60
50
40
30
20
10
0
Percentage by Weight.
Wet Sieve Analysis.


80
70
60
50
40
30
20
10
0
Dry.
Wet
Comparison of Wet & Dry Sieve Test.
ORE #6.
Wet.
Dry.
20
40
60
80
100
100 Thru.
On Mesh.

labor, and also that due to by-products, such as gas, slag and coal-tar products, has been of extreme importance. Wonderful steps have been made in these directions, many of which are merely in their infancy. But this is another subject altogether, and we may therefore say that, from an operative practice standpoint, our efforts during the past ten years have been spent in adapting ourselves




On Mesh
10
20
40
60
80
100
150
200
300
Thru 300
Percentage by Weight.
40
30
20
10
0
Wet Sieve Analysis.
Percentage by Weight.
70
60
50
40
30
20
10
0
Comparison of Wet & Dry Sieve Test.
20
40
60
80
100
Thru 100
Ore NO. 3


On Mesh
10
20
40
60
80
100
150
200
300
Thru
300
Percentage by Weight.
50
40
30
20
10
0
Wet Sieve Analysis.
Percentage by Weight
60
50
40
30
20
10
0
20
40
60
80
100
100
Thru
Comparison of Wet and Dry Sieve Test.

ORE NO. 7.

and plants to the use of material inferior to former mixtures. We may add that through our efforts, the ways and means have been demonstrated, whereby the material with which we are working today can be made equal to that used formerly, and without question will be far more economical in the end. This is illustrated by plants which have installed different equipment, working in the direction of coarse, clean, uniform mixtures, showing remarkable results in every case. In many instances, the results are decidedly apparent, especially when compared to their former practice in previous years. The Mesabas are with us and are going to stay. Our best known coke fields are being depleted, and if, as our present experience is showing and our past experience has shown, that certain conditions will give certain results, it is then only a matter of Engineering, Time, Finance and Policy as to the limit of our Operating Practice. (Applause.)

President Gary: Is there any further discussion under the five minute rule? (After a pause) We shall now have a paper on Merchant Rolling Mills by Mr. Jerome R. George, Chief Engineer of the Morgan Construction Company, Worcester, Massachusetts.

MERCHANT ROLLING MILLS

Jerome R. George

Chief Engineer, Morgan Construction Company, Worcester, Mass.

A well-known writer has recently stated that the rolling mill is the key to all industrial development—that it is, perhaps, the greatest mechanical factor in the civilization of the present day.

The most important and the most interesting of all rolling mills is the so-called Merchant Mill. In fact, the history of all mills for rolling metal shapes, other than flats, commences with and is embraced in the subject of merchant mills.

The first mill with grooved rolls, designed by Henry Cort in Fontley, England, was what we today would call a merchant mill. For some years after the invention of the Cort mill, there were no specialty mills, and all rolling mills produced a variety of sections and materials commensurate with the strength of the roll trains and the demands of the trade.

Rails, wire rods, beams, hoops, skelp, and many other sections now produced on specialty mills, were first developed and rolled on merchant mills, and as a rule the merchant mill is still turning out large quantities of all the above-mentioned shapes in addition to a multitude of other old and new forms.

What Is a Merchant Mill?

It is perhaps natural that a general purpose mill should be rather loosely named. The use of the word "merchant" undoubtedly was first applied to those mills which rolled certain simple sections for stock, and retailed them out later cut to length as ordered. The word is not entirely appropriate as applied to present-day mills

rolling a variety of sections and always to order. In this country, however, a merchant mill is any mill which produces regularly more than one shape, and the word "merchant" is so used by the writer. In England a merchant mill is known as a rod mill. In this country many merchant mills are called bar mills.

The writer has in mind a plant in the Middle West where there are two rolling mills side by side. One mill has a 10-inch train of rolls, and the other a 14-inch train. The former is called a merchant mill, and the latter a bar mill. At another works not far from the border of this State (N. Y.) there is a 10-inch mill which is known throughout the works and on the company books as "The Steel Mill."

All of these mills with different local names roll the same shapes, but different sizes and weights, depending upon the strength of the rolls.

Large Tonnage Rolled on Merchant Mills.

The present normal annual production of the principal rolled steel products in the United States is about as follows:

Rails...........	Rolled	on	Specialty	Mills	3½	Million	G.	T.
Plates	"	"	"	"	3	"	"	"
Sheets	"	"	"	"	3	"	"	"
Wire Rods......	"	"	"	"	2½	"	"	"
Structural Shapes	"	"	"	"	2½	"	"	"
Skelp	"	"	"	"	1	"	"	"
Miscellaneous ...	"	"	"	"	1	"	"	"
Merchant Mill Products				....	8	"	"	"
Total				....	24½			

Thirty-two per cent. of all the steel rolled in the United States is the product of merchant mills, and this proportion would probably hold throughout the world.

With wider and larger markets, many shapes now rolled on merchant mills will undoubtedly be produced on mills especially laid down for the purpose; but it is probable that the merchant mill will nevertheless retain its relative importance as a large producer and continue its important duty of working up business for special mills.

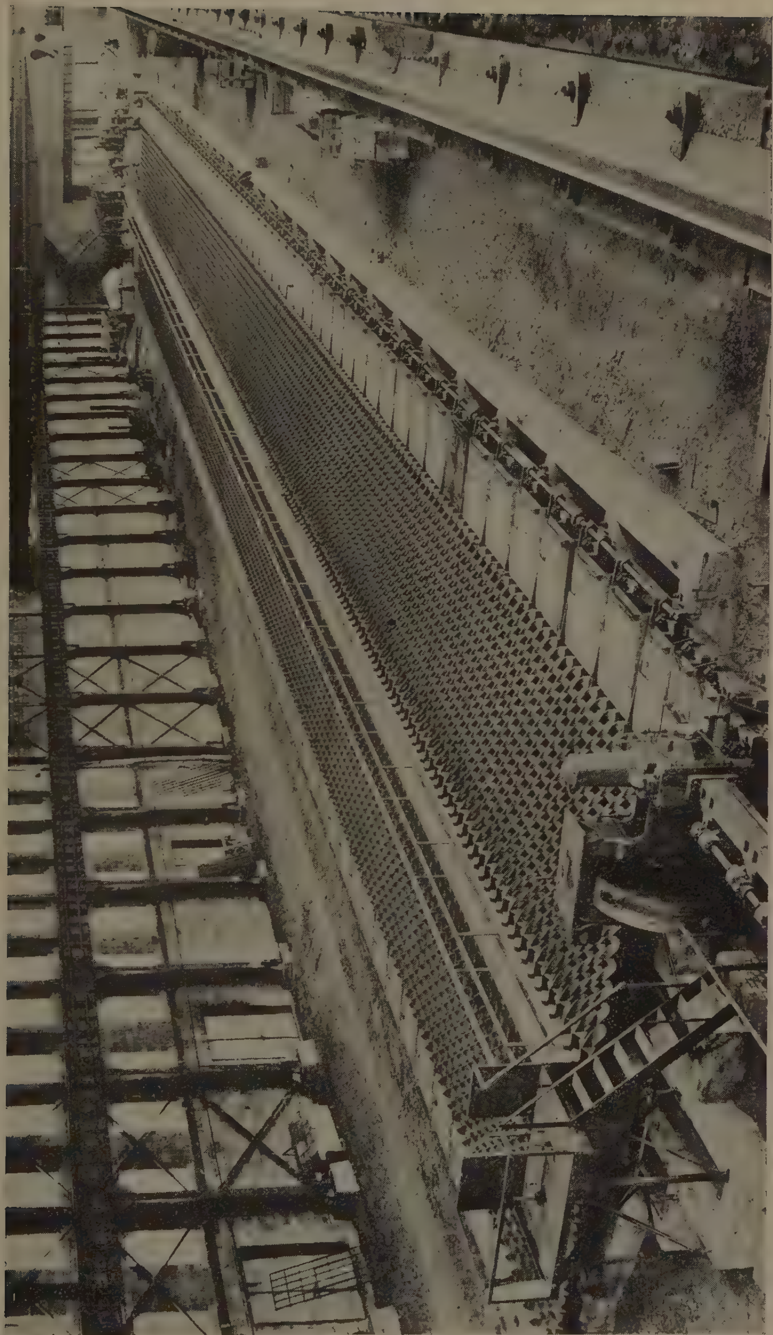
Economies through Specialization.

The United States for some years has held a leading position in the steel business, and in the writer's opinion this has been due in large measure to the early recognition of the economic benefits of highly developed specialized rolling mills. If we are to have an open market and at the same time continue to pay higher wages than our competitors, we must pursue this policy even more vigorously in the future. This does not mean, however, that we can afford to neglect the merchant mill in the slightest degree, because, as stated above, it is the main root of the rolling mill business.

The use of rounds chiefly for bolts and rivets has increased to such an extent that for some years past a number of rolling mills have been employed almost exclusively in the production of round sections. The writer suggests it would be proper and beneficial to give up the name "merchant" as applied to these mills and call them Round Mills. There is always a benefit in understanding and expressing clearly what we are really doing.

Steel bars for reenforcing concrete, used extensively abroad for years and now increasing in use in this country at the rate of about 16 per cent. per annum, constitute a rolled product not requiring the usual accuracy of section, and should be rolled at extremely low cost on special mills.

The pressing demand for greater accuracy of section and temper makes it very desirable to segregate the different classes of work in order, first, that this accurate rolling may be assured, and, second, that the general cost of rolling may be kept down. Just at the present time there is a marked increase in the demand of users of merchant bars for sections rolled more accurately to size, with better surfaces, and particularly in straighter lengths, and this improvement in quality and additional expense to the mill is not accompanied by any corresponding tendency to higher prices.



All the present mechanical means in sight for improving the quality of merchant bars along the above lines involve the use of special auxiliary equipment, which, if installed, should be kept in constant use; and this is a further reason for classifying and segregating merchant mill work as fast as permissible.

Ordinarily, when a special mill is laid down for the purpose of operating exclusively on a product previously rolled on a general merchant mill, the investment per ton of product is cut from 33⅓ to 50 per cent., and the cost of labor is reduced from 50 to 65 per cent. Notable examples are to be found in comparatively recent installations for rolling angles and skelp.

Largely on account of favorable labor conditions in Europe, very few specialty mills have been laid down there, although Germany recently made a beginning along this line by contracting for a few mills of American make. Extraordinary development in highly organized mills in Germany can be looked for upon the restoration of normal business conditions.

The writer hopes he has been able to point out that, along the line of specialization, economies may be accomplished that do not lie within the province of the rolling mill engineer. This is a question of general policy, to be determined by the management.

Operating Difficulties.

Another important point in the hands of the operating department is the systematic scheduling of rolling orders. Up to within a comparatively short time much of the dissatisfaction incident to the merchant mill business resulted from a lack of understanding of the operating difficulties with which these mills have had to contend. The satisfaction of the operator and the customer is dependent upon the infrequency of roll changing, and the importance of this can hardly be exaggerated. A rolling cycle covering the full range of sections in three

or four weeks seems to give the best satisfaction all around.

An ordinary rail mill rolling rails from 25 pounds to 100 pounds per yard, covers a range of weights of only 1 to 4, whereas the most favored merchant mill covers a range of weights of 1 to 10, the ordinary mill a range of 1 to 20, and many merchant mills a range of weights of 1 to 60. If, in addition to meeting these extreme conditions, a roller is asked to roll rounds, squares, nut iron, ovals, flats, angles, rails, beams, channels and a multitude of other shapes, and change without notice from one section to another to suit the demands of the sales department and the customer, the result is sure to be dissatisfaction all along the line.

For almost a century the merchant mill retained its original simplicity, and the minor changes and improvements adopted were confined almost wholly to the roll trains. Billets were charged, drawn and fed to the mill by hand. The finished product was rolled in short lengths so that it could be manipulated on the cooling floor by hand.

In the past twenty years all this has changed, and the roll trains of modern mills are almost lost in the mass of mechanical equipment designed to convey the metal to and from the rolls. The cost of a modern notched cooling bed alone equals or exceeds the former cost of an entire mill, and the mechanical problems involved are extremely difficult. Fig. 1 is a photograph of one type of notched bed of moderate length with the roll train in the background scarcely visible.

The Mechanical Cooling Bed.

The writer does not believe it proper at this writing to go extensively into the many intricate details of modern merchant mills, but brief reference to the mechanical bed should be of interest. The principal feature lies in the rack notch, which presents two surfaces at 90 degrees opposed to gravity. (See Fig. 2.) The beds consist of

live roll conveyors for receiving the stock as delivered from the mill at a speed in some cases up to about 25 feet per second, and with less than one second clearance between bars; means for accurately stopping the stock without injury, and transferring it to the cooling racks; notched racks close enough together to support the lightest material rolled, and so designed that the stock is

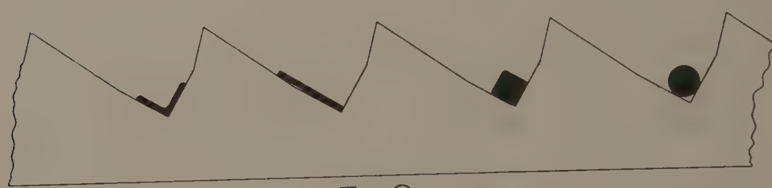


FIG-2
DIAGRAM OF COOLING BED RACK

MAY 1-1915.

automatically advanced across the bed; a receiving and assembling table at the end of the racks with means for transferring the assembled bars to the front shear table. All the various operations are performed by electric power. Notwithstanding the fact that these machines are constantly subjected to scale and varying degrees of heat, they have been developed to such a point of mechanical perfection that the cost of operation and maintenance is practically negligible. It will be of interest to learn that one double bed installed in a 10-inch merchant mill, and reduced to the smallest practicable number of parts, contained in all 96,225 pieces exclusive of the motor parts.

Certain types of merchant mills producing a limited range of flats, large rounds, etc., do not have and do not require the notched type of bed; but practically all modern merchant mills are now equipped with some form of mechanical cooling bed. The large tonnage and superior quality of material, as well as the low cost of production which obtains in modern merchant mills, could not be approached, particularly in small mills. without the long mechanical bed with notched racks.

A most fascinating feature of these long beds, which are made at present in lengths up to 500 feet, is presented in the opportunity to observe the peculiar effect of molecular changes incident to the cooling of the hot bars. After the bars reach the bed they first contract, then expand several inches, and then finally contract several feet. The movement of the ends of the long bars as they travel first in one direction, and then in another, is surprisingly rapid.

Economies through Improved Machinery.

Although the modern merchant mill represents a large investment of capital, the cost per ton of product is no greater than the cost of the lowest type of hand mill laid down under equal conditions. The writer's experience has been that all kinds of merchant mills cost from \$5.00 to \$6.50 per ton of product per annum, this investment covering everything necessary to equip and start the mill excepting the land.

Aside from some sacrifice in flexibility, the modern merchant mill is a great improvement over the mills in use twenty years ago. In the space of time mentioned, the tons produced per man has been increased 400 to 500 per cent., and all the work made infinitely easier and safer. The loss in crops and shorts has been reduced 75 per cent. The cost of heating has been reduced 50 per cent., and the total cost of putting billets into finished bars has been reduced on the average from 50 to 60 per cent. The above-mentioned economies have been accomplished in the face of new and more exacting requirements as to accuracy of gauge, straightness and temper. The ring and limit gauge and the autocratic inspector were little known in the merchant mills of twenty years ago.

The United States can claim all the credit for the entire development of merchant mills during the last twenty or twenty-five years. Whether or not we can retain our leadership in this work will depend almost entirely upon the restoration of favorable business con-

ditions under which funds will again be available for expansion and development.

Development of Merchant Mills.

Concerning the technical development of the merchant mill, volumes could be written if one ventured into the

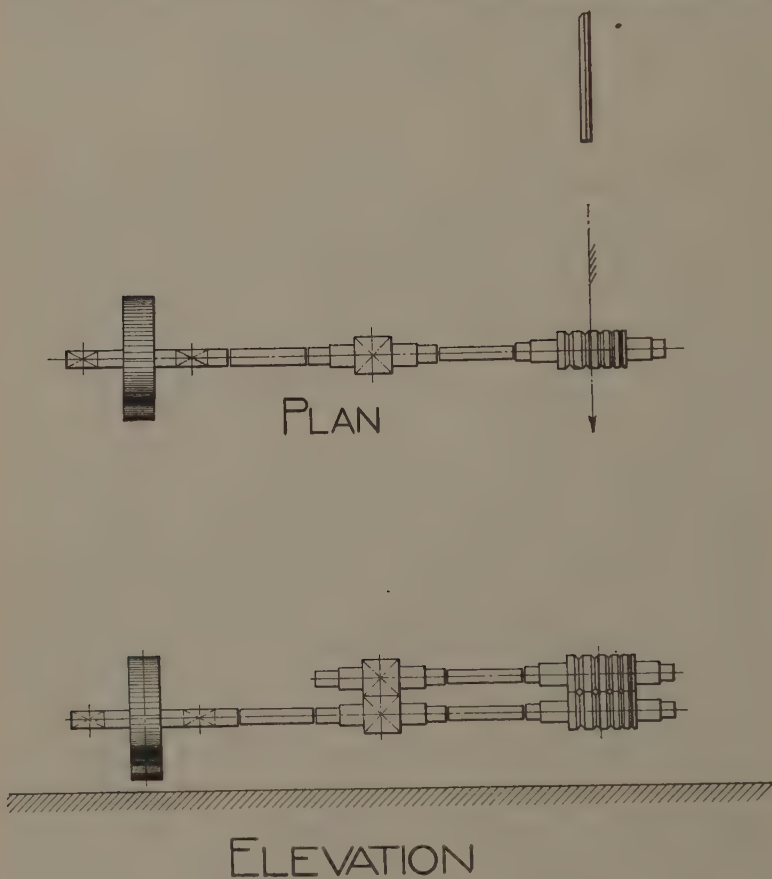


FIG. 3
DIAGRAM
MERCHANT ROLLING MILL
TWO HIGH TRAIN

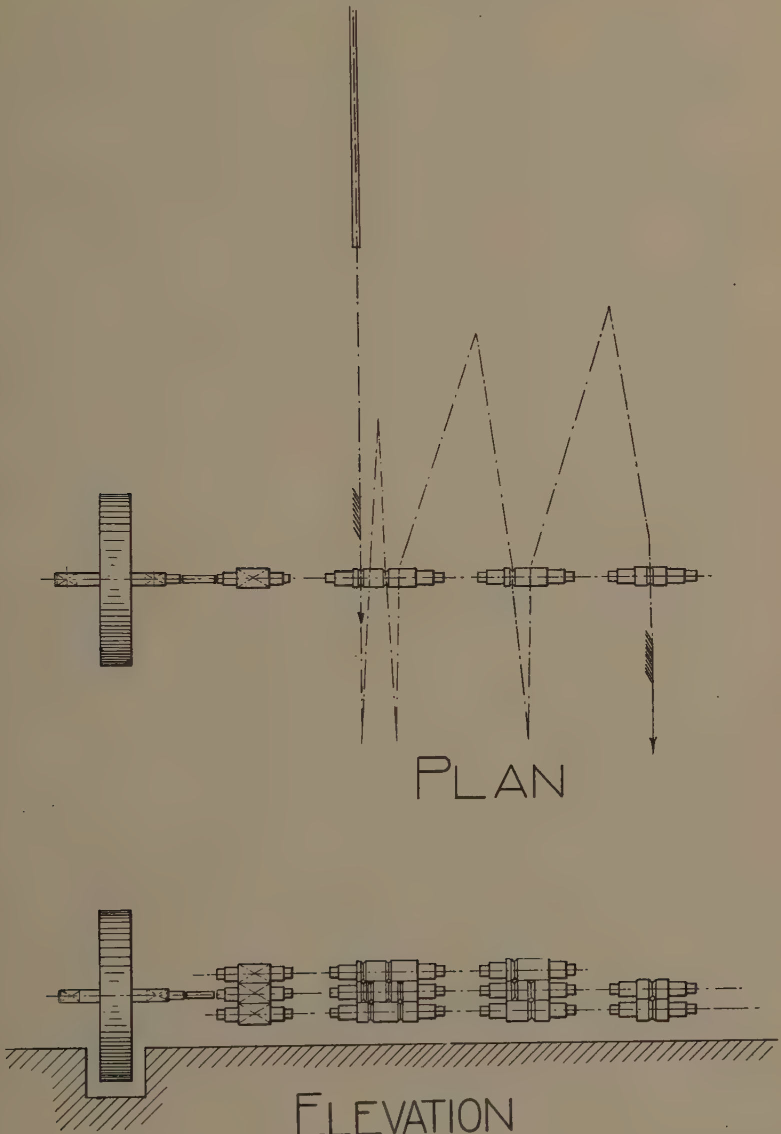


FIG. 4.
DIAGRAM
MERCHANT ROLLING MILL
WITH
THREE HIGH TRAIN

field of details. The writer will, however, endeavor to present in brief outline the most important steps relating to changes in arrangement of rolls and the introduction of important auxiliary equipment.

For many years all merchant bars were rolled on the simplest possible form of mill, namely, the two-high train (Fig. 3). The bars were given a reduction by passing between the rolls and returned over the top roll for the next succeeding pass. The length finished was usually about 16 feet to 20 feet. Only the simplest forms of guides were used. Then, as now, the most common sections rolled were rounds, and these were made quite true and accurate by first rolling a round bar slightly above the desired area and then passing it through a final finishing groove several times, the roller holding the bar with tongs and turning it 45 degrees to 90 degrees between each pass until the desired roundness was obtained.

The three-high train (Fig. 4) was designed to avoid the idle pass over the top roll, and soon replaced the two-high mills and brought about a considerable economy of labor. The number of stands of rolls was increased with the object of enlarging the size of billets and decreasing the number of passes per stand.

Since the tonnage was still limited by the time required to pass the bar several times through the single finishing groove, it was necessary to progress that some means be found to make a round in one pass in the finishing groove. It was finally discovered that if an oval section of certain proportions was held up by metal guides on the receiving side of the finishing rolls, good commercial rounds could be made in one pass. This really great discovery introduced the "Guide" mill of today. The finishing of long lengths commenced at this point of development.

In order to get more tonnage on the smaller mills, it was necessary to run the rolls at a greater speed, and the speed was gradually increased up to the point where trouble was experienced in the roughing end of the train

because of the rolls not "taking" the billet. To overcome this trouble the first roughing roll was set up independent of the finishing train and run at a lower speed (Fig. 5).

The next step forward in the production of light sections came from a new method of working the bars in the

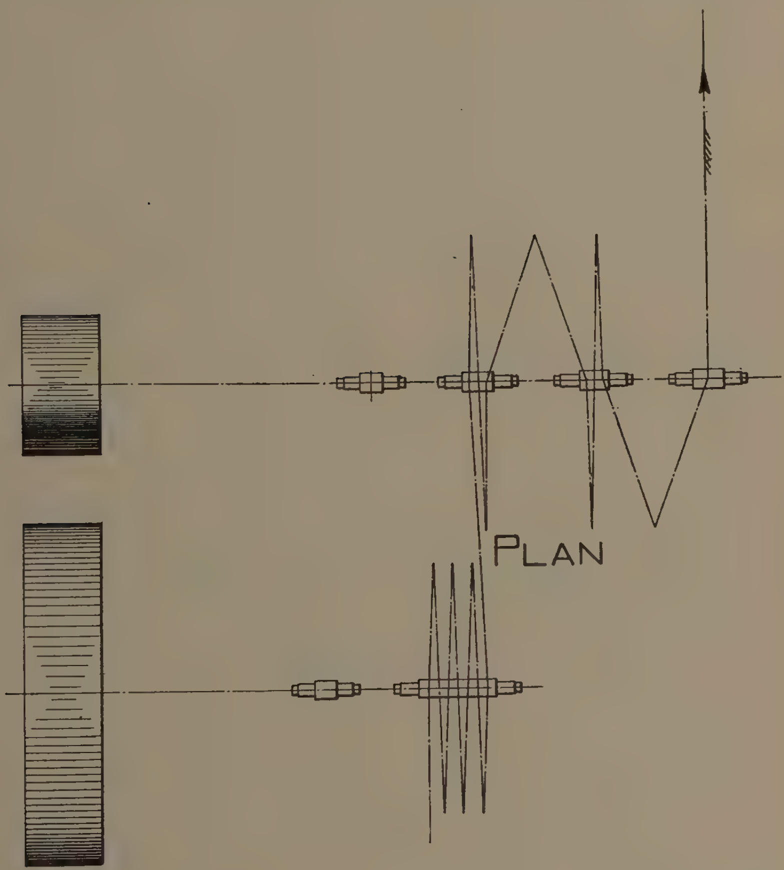


FIG. 5
DIAGRAM
MERCHANT ROLLING MILL
WITH
INDEPENDENT THREE HIGH
ROUGHING TRAIN

finishing train. The early method was to allow the bar to run out on the floor and pick up the last end and enter it into the next pass. It was found that a man could catch the first end in a pair of tongs and turn it back into

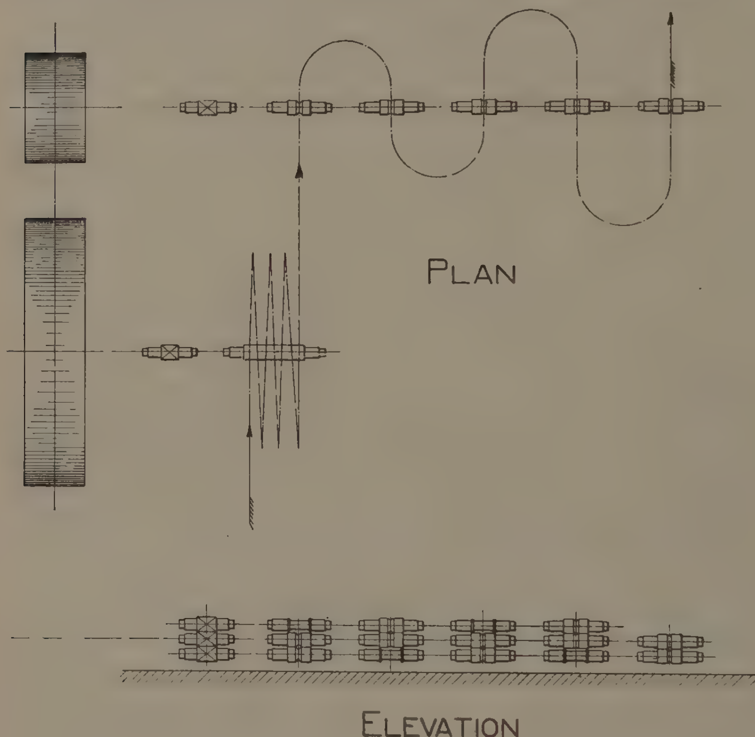
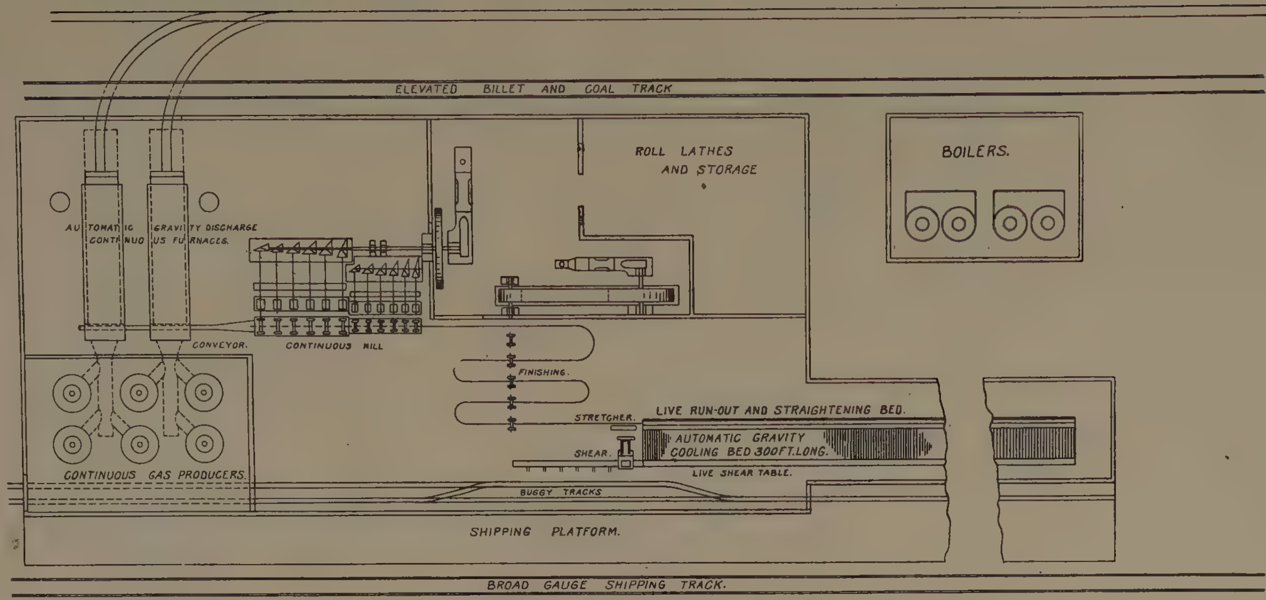


FIG. 6
DIAGRAM
MERCHANT ROLLING MILL
WITH
ALTERNATE TWO HIGH FINISHING TRAIN

MAY 1-1915

the next pass, forming a loop which overfed onto the floor. As it was easier to turn in the bar from one roll to another than into another pass in the same roll, the alternate two-high mill came into use at this stage. (See Fig. 6.) The alternate two-high mill later reached its greatest point of usefulness in the Garrett type of rod



COMPOSITE PLAN OF FOUR EARLY SEMI-CONT. MERCHANT MILLS.

Fig. 7. Diagram

Merchant Rolling Mill With Continuous Roughing Trains

mills. Overfeed in the loop was slightly reduced by stepping up the roll diameters as the section was reduced.

A condition was soon brought about where the production was again limited by the hand-fed roughing train. Up to this time no mechanical appliance of any nature excepting the hook and tongs had been employed about the roughing or finishing trains. About this time the steel business in this country experienced a severe and prolonged depression combined with labor troubles, and this led to the installation of a continuous roughing train in the hope of eliminating the troublesome and expensive crew of roughers on the hand mill. (See Fig. 7.)

Notwithstanding prejudice and some bad details of construction, the continuous roughing train proved a commercial success for general merchant mill work. Continuous roughing trains were soon added to many existing merchant mills and to the Garrett wire rod mills.

The usual number of men, known as roughers, employed about a stand of hand roughing rolls amounted to twelve in twenty-four hours, and in 1900, working under 140 card Amalgamated Scale, the men averaged to earn $3.60 for eight hours on the smallest tonnage mills. The Continuous Mill displaced nine of these men and in most cases increased the output of the mill 50 per cent.

At about this period the Continuous Heating Furnace was improved at the delivery end by the gravity end discharge, and this type of furnace came into general and permanent use for all kinds of merchant work.

The notched mechanical cooling bed of greatly increased length was introduced about the same time as the continuous roughing train, and the length of finished bars increased from three to four times.

It was a simple matter to speed up a continuous roughing train to overfeed the finishing pass, and so the output of the mill was again limited at the finishing train. Some considerable improvement in tonnage and yield was in sight, providing bars could be finished in longer lengths and the cooling bed no longer presented any obstacles.

Uniform Heat Treatment.

The problem of further improvement, therefore, resolved itself into a question of uniform heat treatment throughout the length of the finished bars. This was partially solved by an arrangement of rolls in the finishing train as shown in Fig. 8. The principal feature of this

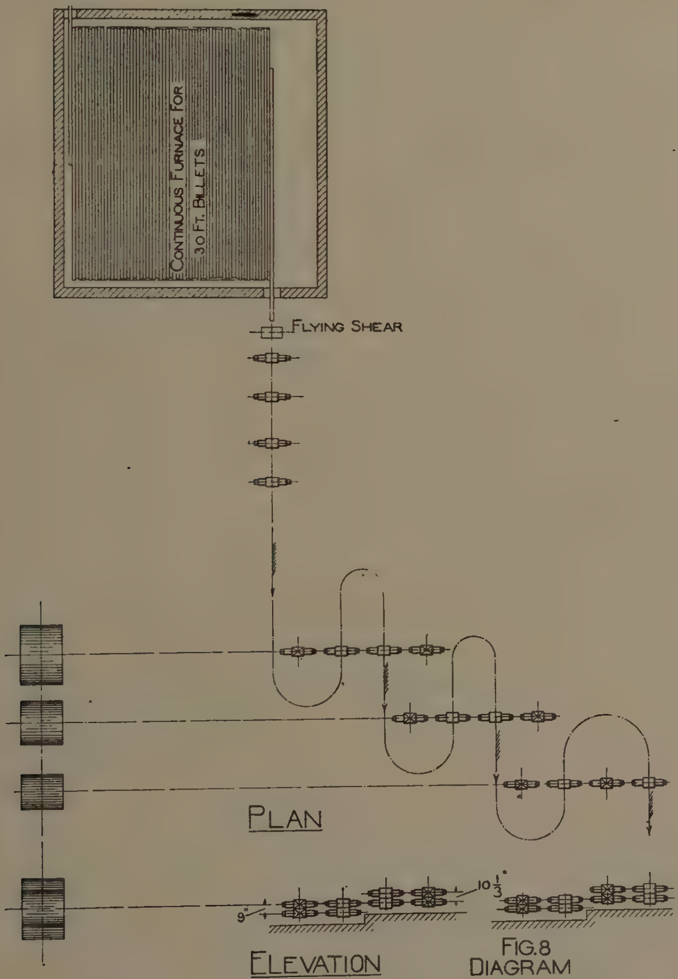


FIG. 8
DIAGRAM
MERCHANT ROLLING MILL
WITH
EDWARDS SEMI-CONTINUOUS FINISHING TRAINS
FURNACE FOR 30 FT. BILLETS

MAY 1-1915

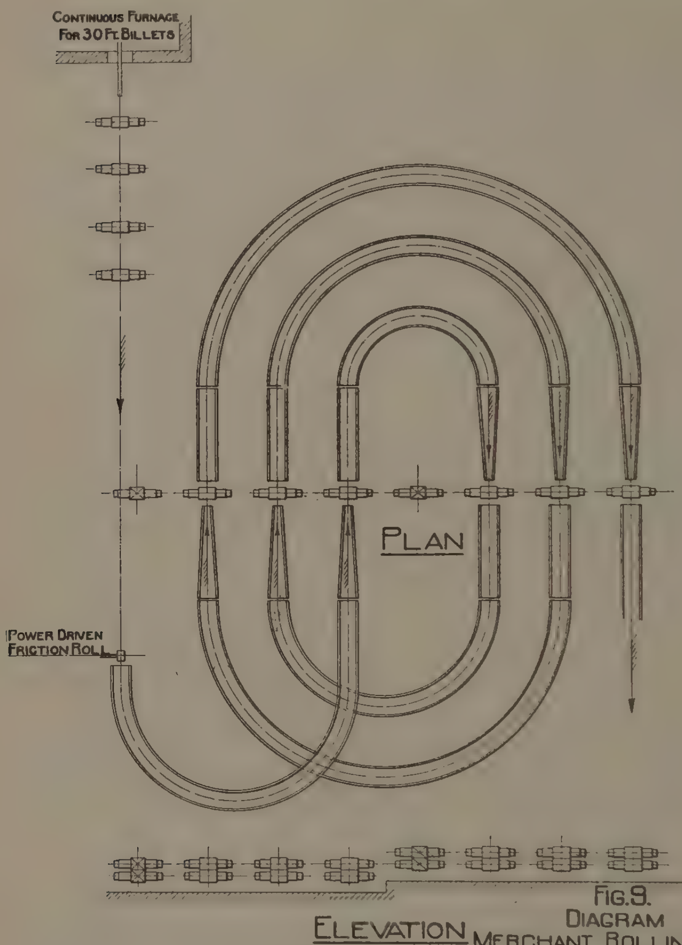


FIG. 9.
DIAGRAM
MERCHANT ROLLING MILL
FOR HEAVY SECTIONS
FINISHING TRAIN
EQUIPPED THROUGHOUT
WITH AUTOMATIC REPEATERS

arrangement is that the peripheral speed of each roll is enough less than the speed of the one following to hold back the metal so that much of it lies in the furnace instead of upon the mill floor.

The problem was completely solved by the use of 30-foot small billets heated in a furnace placed close by and immediately in front of the first stand of rolls. With this arrangement of furnace and finishing rolls, the time of

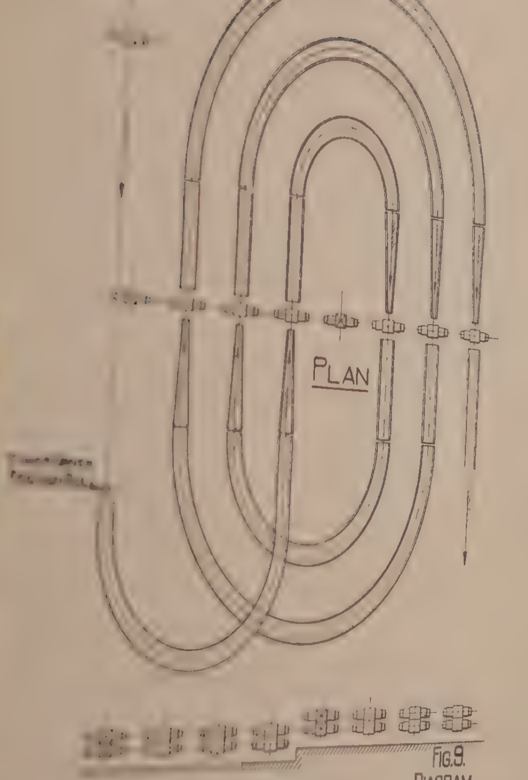
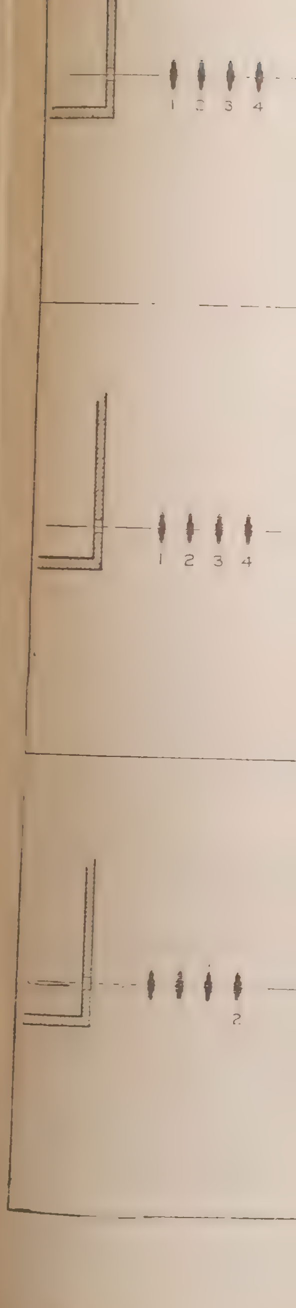


FIG. 9.
DIAGRAM
MERCHANT ROLLING MILL
FOR HEAVY SECTIONS
FINISHING TRAIN
EQUIPPED THROUGHOUT
WITH AUTOMATIC REPEATERS
MAY 1915



arrangement is that the peripheral speed of each roll is enough less than the speed of the one following to hold back the metal so that much of it lies in the furnace instead of upon the mill floor.

The problem was completely solved by the use of 30-foot small billets heated in a furnace placed close by and immediately in front of the first stand of rolls. With this arrangement of furnace and finishing rolls, the time of

exposure from furnace to finishing pass is substantially the same for both ends of the bar regardless of the length finished. The short distance between furnace and mill was made possible by the use of a flying shear. The novel arrangement of roll and pinion housings retained all the advantages of the alternate two-high construction and none of its inherent disadvantages. Mills of this type produce regularly 10,000 tons per month, and on a good day's run will turn out 750 gross tons of ¾-inch rounds.

Another type of mill for heavier sections is shown in Fig. 9. This mill is used for producing sections too stiff to be turned in by hand and is entirely automatic in operation. Note the entire absence of roller tables and mechanical transfers. The first successful employment of mechanical repeaters on both sides of a merchant mill train was made in a mill of this type. One of these mills produces more than 150,000 tons of bars per annum.

For rolling heavier merchant sections there are several types of improved mills, notably the three-high mill with traveling roller tables, and the Slick cross-country mill with stationary roller tables. These mills permit of the maximum flexibility and produce large tonnages. The tendency of the times, however, is to revert to the two-high construction of the original Cort mill for all kinds of rolling, on account of its simplicity and great stiffness.

Some Recent Improvements.

From the beginning two fundamental difficulties have obtained in all general merchant mills, due to the wide range of sections required to be rolled on a given mill, and the problem for the future to solve is the elimination of these difficulties, which are as follows:

1st. Lost time during roll changes.

2d. Extreme variation in output from light to heavy sections.

Spare finishing trains seem to be the remedy for the first. Speed changes can be employed to only a limited

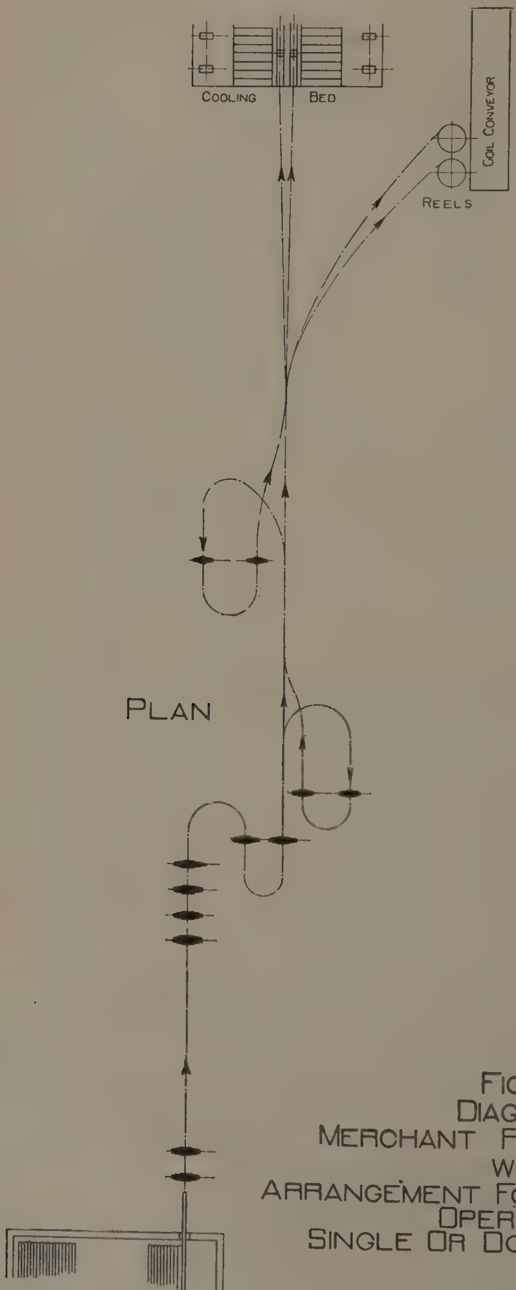


FIG. 11
DIAGRAM
MERCHANT ROLLING MILL
WITH
ARRANGEMENT FOR JOBBING WORK
OPERATED
SINGLE OR DOUBLE STRAND

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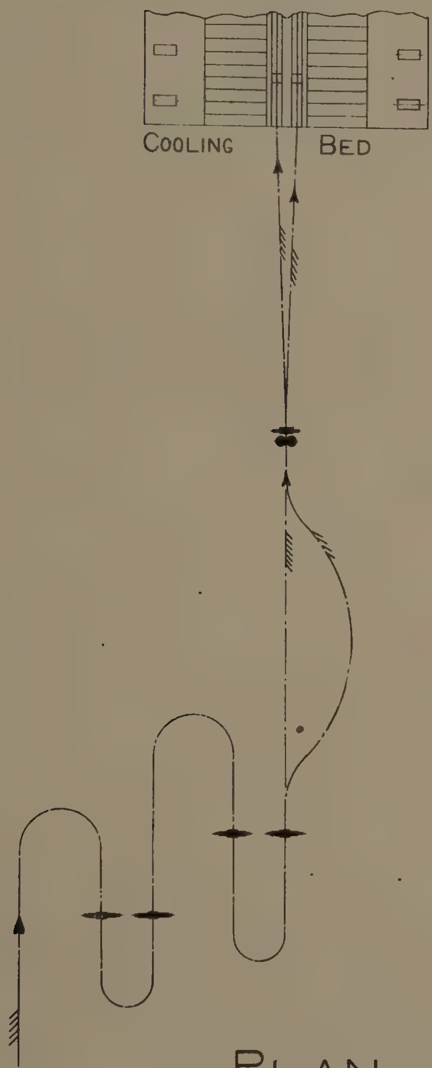


PLAN

FIG. 12
DIAGRAM
MERCHANT ROLLING MILL
WITH
SUPPLEMENTAL SIZING TRAIN

extent to correct the second trouble, and therefore it seems necessary to increase or decrease the number of strands rolled in inverse proportion to the weight of bar to be rolled. For 8-inch, 9-inch and 10-inch mill work the arrangement of rolls shown in Figs. 10 and 11 seems to offer a simple solution of both of these difficulties.

Improvement in mill construction, together with the perfection of the art of roll design and guide design, has made possible the production of sections of almost unbelievable accuracy; but the insistent demand of many buyers of steel for extreme exactness of round sections has made it necessary to provide means for rolling hot rounds with almost the accuracy of cold-drawn bars.

To meet this new requirement of the steel trade, a special mill has been evolved with which the general trade may not be familiar, although it has been in successful operation for some months. This new mill, curiously enough, works upon the same principle as employed in the original merchant mill for securing an accurate and true round, but, of course, without reverting to hand labor. Two pairs of rolls set at 90 degrees to each other are mounted so close together in a common housing that the leading pair performs the function of the man with the tongs on the old two-high hand mill. As in the old-time mill, a round bar slightly larger in area than the finished bar is first made in the regular way and then passed through this sizing mill, which is located between the regular finishing train and the cooling bed (Fig. 12). The usual best rolling practice of plus or minus about 7/1000ths of an inch in diameter has by this machine been reduced 50 per cent.

President Gary: Is there any discussion under the five minute rule? (After a pause.) The Institute is now in recess until two o'clock.

NOON RECESS.

During the noon recess the members of the Institute were the guests of the Institute at a buffet luncheon. During the noon recess, also, the Directors of the Institute held their regular monthly meeting.

At two o'clock the Institute was again called to order, Judge Gary in the chair.

President Gary: The Institute will please be in order. We will now have a paper on the Commercial Production of Sound and Homogeneous Steel by Mr. Edward F. Kenney, Metallurgical Engineer of the Cambria Steel Company.

THE COMMERCIAL PRODUCTION OF SOUND AND HOMOGENEOUS STEEL

Edward F. Kenney
Metallurgical Engineer, Cambria Steel Co., Johnstown, Pa.

The ideal steel is that which contains no break in the continuity of the metal, and in addition contains the same proportions in all its parts of all constituents which affect its strength or ductility. The lack of continuity appears in general in three forms: 1, piping; 2, blow-holes, and 3, slag inclusions. The absence of the homogeneity referred to is the result of a segregation, due to liquidation, of the elements other than iron which are present in steel either from design or as impurities.

Of the first three objectionable features, the slag inclusions may be dismissed with the statement that they do not occur to any considerable extent in well-made steel, but the piping and blow-holes are necessary evils, and one or the other will normally be present in a mass of solidified steel for the reason that the steel when solid occupies a smaller volume than when it was molten. As a mass of steel solidifies from the outside, this solidification of the outer steel approximately determines the shape and size of the mass. The molten interior continues to shrink as it cools, and unless the deficiency is taken up by bubbles of gas (blow-holes) forming in the interior, there will be a void due to the shrinkage. This shrinkage cavity is known as a pipe, and is distinguished from the other types of cavities referred to above as blow-holes.

Blow-holes are bubbles of gas which were enmeshed in the solidifying metal, before they could release themselves and rise to the top of the metal. The refining of steel as carried on in the Bessemer or open hearth processes is an oxidizing operation, and there is of

necessity a considerable amount of oxygen present in the bath of metal, mostly combined with iron. There is also present an appreciable amount of carbon, and a combination of the two elements produces gaseous compounds. This reaction takes place in all steels which have not been thoroughly deoxidized, and therefore all such steels contain gas bubbles or blow-holes.

Carbon monoxide and other gases are more or less soluble in steel; the degree of solubility generally increasing with the temperature, and therefore considerable quantities of gas are thrown out of solution as the steel cools. Gas bubbles form in such quantity in a lively steel that the steel appears to boil quite violently in the molds; much of the gas evolved escapes, but some of the bubbles are held by the solidifying metal. The effect of these gas bubbles on the steel is dependent on their location. If they are close to the surface they are likely to result in surface flaws in the steel. The blow-holes may so weaken the exterior of the ingot as to cause it to tear in the early passes of blooming, or by their being exposed due to oxidization of the thin skin of metal between them and the exterior of the ingot. When so exposed their surfaces are oxidized and they result in a large number of small seams unfitting the steel for many uses.

Some persons have considered as harmless the deeper-seated blow-holes, but those, too, while much less objectionable than peripheral blow-holes, often leave traces (after being welded up) in the shape of lower carbon areas which are weaker than the surrounding metal.

In crystallization from most solutions there is a selective freezing of the various substances in the order of their temperatures of solidification, and steel follows the general rule. Of the elements ordinarily present in steel, the degree with which they segregate is dependent on the variation of their qualities from those of iron. For instance, manganese, which is very similar to iron in atomic weight and other characteristics, segregates only to a slight degree, while sulphur, phosphorus and carbon,

which differ widely in their nature from iron, segregate markedly. As the presence of some of these elements affects vitally the strength and ductility of the steel, the segregated portions are generally harder and less ductile than those not segregated, and this difference in physical qualities prevents the best results in resisting stresses produced in the steel in service. If we subject to simple tensile stress a bar of steel which is highly segregated, the difference in behavior of the hard center, rich in the metalloids as compared with the purer outside, is so marked that the ductility of the center will be exhausted, and failure will take place quite appreciably before similar failure takes place on the exterior. This effect is clearly shown in the accompanying photograph of a section of steel rod which has been cold drawn. The center is highly segregated, as shown by the etching, and

corroborated by analysis. In the severe distortion produced by drawing, its ductility has been exhausted, and internal fractures have occurred, although the exterior is apparently capable of yet greater elongation. It is quite evident that material so constituted is not fit for use in any important engineering structure, as the ordinary assumption that the stresses would be distributed and resisted uniformly by the entire section would not be true. On the contrary, the yielding of the more ductile portion concentrates the stresses on the less ductile, with the results shown in the illustration.

A somewhat different development from the same cause is shown in the type of rail failure known commonly as "split head." In this case the exterior metal at the top of the head is distorted by the intense pressure on the area of contact with the wheel. This distortion results in lateral flow, but when the rail is segregated the hard

interior metal does not possess sufficient ductility to permit its following the flow of the exterior, and an interior longitudinal fissure of progressive type results. This extends vertically through the head and longitudinally along the rail, and ultimately results in one side of the rail head breaking off, unless the failure is detected and the rail removed from service. This type of failure is found almost exclusively in segregated steel.

The growing use of heat treatment of steels for forgings is giving an added impetus to the movement toward securing uniformity in steels. The rapid cooling of the steel in quenching induces severe stresses. If these stresses are uniform and the resistance of the steel is uniform, the quenching can be done without damage to the steel; but if the hardeners which are affected by quenching are not uniformly distributed—if one part of the member being quenched has the hardeners in greater quantity in one portion, that portion will be subjected to greater stresses when quenched. These cooling stresses are frequently sufficient to crack steel which is segregated.

Steel which is required to be heat treated is generally treated only after a considerable amount has been expended on it in forging, and a failure after this expenditure is so costly that it will unquestionably pay to put a little more expense into the making of the steel, than to risk rejection of the more expensive forging, either from cracking in the quenching or from not meeting the required tests.

The general characteristics of segregation are fairly well known, though some of the causes are not so clearly understood, but the following statements will probably not be disputed:

1—Segregation is greatest in the portion of the ingot which freezes last.

2—It is most marked in elements whose characteristics differ most widely from those of iron.

3—It is increased in steel which is lively, and decreased in steel which lies dead.

4—It is greater in steel teemed at high temperatures than in steel teemed at more moderate heats.

1—The widely prevalent knowledge of the first of these statements has resulted in the application of cropping as the remedy, and there is little doubt that if we could be certain of knowing that there was steady progressive freezing by which the segregated metal, squeezed out of all other portions of the ingot by the solidification of the purer metal, was brought to some certain part of the ingot, we could get rid of the segregation in this way. Unfortunately, the type of ingot mostly used is so shaped that it is by no means certain that all the segregation occurs at the top of the ingot. This is illustrated on Plates 1, 2, and 3. The two ingots and two blooms were from the same heat of steel. The chemical survey of these shows quite clearly that in the process of freezing, bridges have formed in the ingots somewhat above the center and divided the molten metal into two pools, each freezing independently of the other. In addition to the principal center of segregation and shrinkage near the top, there has been a secondary one about halfway down the ingot. The higher content of the metalloids at the bottom of the second bloom and top of the third, rolled from ingot No. 3, establishes this fact, and in the case of the blooms from ingot No. 4, a clearly defined shrinkage cavity was found in connection with the segregation. Instances of this kind are only too common in the ordinary type of ingots. If we wish to be certain that the segregation is at the top we must use ingots of the inverted type, or in some other way insure the progressive freezing from the bottom upwards, without the possibility of bridging. This is somewhat affected by the design of the ingot mold and stool—the amount of cool metal available to absorb heat affecting the rapidity of the freezing at any point. It has been common practice for years to vary the thickness of the walls of the ingot mold, making them heavier at the bottom than at the top, so as to conduct the heat more rapidly from the


SPLIT INGOTS C.O.H. HEAT Nº 28560.
LADLE ANALYSIS C .715 P .020 S .026 Mn .59
Nº 1.- INGOT ALLOWED TO COOL AFTER CASTING
Nº 2.- INGOT HEATED TO ROLLING TEMPERATURE AND ALLOWED TO COOL.

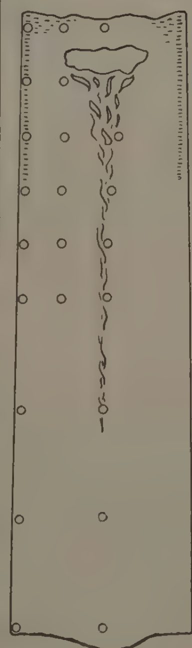
PLATE I

SPLIT INGOTS C. O. H. HEAT Nº 28560

LADLE ANALYSIS C 715 P 020 S.026 Mn 59

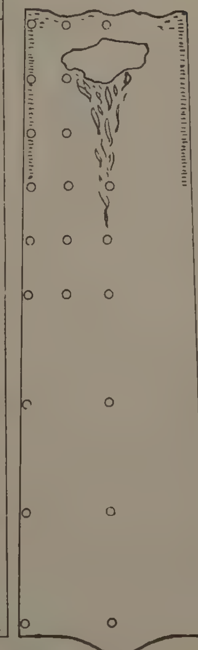
Nº 1- Ingot allowed to cool.
Volume of Pipe Cavity = 179.4 Cu.In
Discard = 65.6 %

	OUTSIDE C P S Mn	MIDWAY C P S Mn	CENTER C P S Mn
1	.778 019 023 52	702 021 019 48	661 020 018 53
2	.632 020 017 53	.806 025 024 54	
3	.680 017 021 53	.810 025 023 .53	.927 033 037 58
4	.720 016 023 .52	.796 023 028 54	.810 025 030 55
5	.722 019 024 .52	.828 022 029 .55	.724 020 025 53
6	.712 018 023 .54	.750 023 026 .57	.750 020 025 52
7	.728 020 023 .54		.690 018 025 53
8	.738 019 024 .54		.640 018 021 53
9	.740 022 023 .54		.684 017 023 52



Nº 2- Ingot heated to Rolling Temperature and allowed to cool. Volume of Pipe Cavity 262.4 Cu.In.
Discard = 33.8 %

	OUTSIDE C P S Mn	MIDWAY C P S Mn	CENTER C P S Mn
1	670 013 020 52	665 020 019 52	730 016 .022 53
2	.670 014 019 51	770 017 023 55	
3	.694 014 021 53	.728 018 020 53	
4	670 017 021 55	802 018 026 .55	876 025 035 57
5	.716 020 024 54	822 022 030 55	830 024 031 55
6	.656 019 024 54	810 022 029 54	.700 020 027 54
7	.710 020 024 56		830 023 030 55
8	.710 020 022 54		660 026 020 52
9	722 020 022 54		634 020 020 .54



DEPT OF TESTS
OCT 1914

PLATE II

SPLIT BLOOMS
C.O.H. HEAT No 28560.
LADLE ANALYSIS C.715 P.020 S.026 Mn.59

Blooms cut from No 4 Ingot which was allowed to cool, then heated and rolled.

	CENTER C	P	S	Mn	OUTSIDE C	P	S	Mn
1	.644	.015	023	55	.572	014	019	55
2	810	018	022	55	660	.014	019	53
3	984	033	044	60	.710	016	023	54
4	.990	036	052	58	.730	016	022	53
5	1.020	036	060	60	.720	020	021	54
6	.970	026	.041	57	.750	021	026	.55
7	852	025	031	55	.750	.022	.025	55
8	780	019	025	.53	.704	018	.023	.52
9	800	021	027	54	.744	020	025	52
10	774	.018	.024	53	.730	018	.024	54
11	.788	023	025	.52	754	.019	025	55
12	.866	024	.033	.53	.716	.019	025	54
13	750	020	026	.51	.686	016	024	52
14	766	022	.027	.52	.753	020	.025	54
15	.702	.019	026	.51	704	019	024	.53
16	.706	020	.023	.53	.700	.019	.026	53
17	.742	.019	.022	53	.726	.020	024	.52
18	.720	020	.024	.51	.690	.019	.023	.51
19	.678	.018	.022	.51	700	.019	.025	.52

Blooms cut from No 3 Ingot which was heated and rolled in the usual way

	CENTER C	P	S	Mn	OUTSIDE C	P	S	Mn
1	.648	014	020	51	643	015	.019	53
2	.754	017	022	54	.640	017	019	53
3	.800	017	023	58	690	017	019	55
4	1.093	039	052	62	.700	016	019	52
5	1.070	038	052	58	.782	015	020	53
6	.944	029	042	57	.750	020	024	54
7	.896	027	036	55	752	020	024	55
8	.746	018	025	52	.700	.021	023	52
9	.766	023	027	.52	.730	.019	.023	54
10	760	022	028	55	.751	021	.025	.55
11	.828	.023	.027	55	.740	.021	.027	.53
12	.803	.025	034	54	.736	.020	.024	52
13	.784	019	023	54	730	020	.023	52
14	.690	019	022	52	.722	022	025	52
15	.694	020	023	.52	700	018	.024	53
16	782	022	.029	53	.774	019	024	52
17	.796	.021	.024	.52	728	021	.023	53
18	.768	026	033	55	.700	.020	.024	.54
19	.716	019	.023	.52	.688	.020	.025	.53

DEPT. OF TESTS.
OCT 1914

PLATE III

bottom of the ingot. In the writer's judgment this means is not as efficient as is sometimes expected, because the shrinkage of the cooling ingot and the expansion of the mold, due to its being heated by the ingot, soon produces a space between ingot and mold. This space is filled with air which is a poor conductor.

2—The elements ordinarily present in plain carbon steels which are generally considered as of most importance are carbon, phosphorus, sulphur and manganese. The degree in which they segregate is expressed by the order of sulphur, phosphorus, carbon and manganese, the latter showing very slight tendency. Considerable variations in the manganese content are sometimes encountered, but they do not follow the segregation of the other elements, and are generally not due to liquidation, but to irregular melting of the ferromanganese, and consequently imperfect mixing. The other three elements show marked effect of selective freezing in the steel, and seem to follow the same general lines; where an excess of one is present in any locality in an ingot, the others are probably segregated at that same point.

3—Wild or lively steel is steel in which there is marked ebullition due to evolution of gas. These gas bubbles, as stated previously, are largely the product of a reaction between oxides and carbon contained in the steel. In addition to these there are others which are the result of the throwing out of solution of gas which has been held in the steel and which is thrown off as the steel cools. Because of the great disparity of the density of molten steel and the gases, the bubbles strive to rise to the top. The great number of bubbles rising produce active currents in the molten ingot, and these currents carry up with them the more fluid segregate which is left as the purer metal crystallizes out in the freezing. This segregated material having a low specific gravity, remains at the upper portion of the ingot after being collected by the currents and carried there. Aside from the effect of the currents referred to, there is considerable tendency

of the metal rich in impurities, to rise to the top due to this lower specific gravity. Killed steels contain only small quantities of gas; there are consequently no very active currents in the cooling metal, and therefore it solidifies more quickly and is much more uniform.

4—As the capacity for holding gases in solution is greater at high temperatures than low, it follows that steel cast at relatively low temperatures will, other things being equal, carry less gas into the ingot molds than if the same steel were cast at higher temperature. As less gas is contained, less will be thrown out of solution, there will be fewer blow-holes, less active currents and consequently less segregation. In addition to this, the lower casting temperature reduces the time occupied in cooling the steel to its freezing point, and this reduction of the time of freezing reduces the tendency toward selective freezing of the various constituents.

Prevention of Segregation.

The minimizing of the tendency toward segregation can be effected in two ways—thermally and chemically, the latter being much more effective than the former, but the combination of the two producing the best results. The thermal remedy is teeming the steel at a temperature just high enough to insure clean pouring and avoiding excessive skull in ladle, and danger of freezing up the nozzle. This lessens the range of temperature through which the steel must cool before solidifying, and also lessens the differential of temperature between the various parts of the ingot in cooling. The further thermal remedy of rapid cooling of the ingots involves other considerations which would be uneconomical in commercial practice, so that we will not consider them.

The chemical remedy is simply deoxidation; removing the principal source of the production of gas bubbles. If there is no oxygen in the steel to combine with the carbon, carbon monoxide, which plays the principal part in the formation of blow-holes, will not be formed.

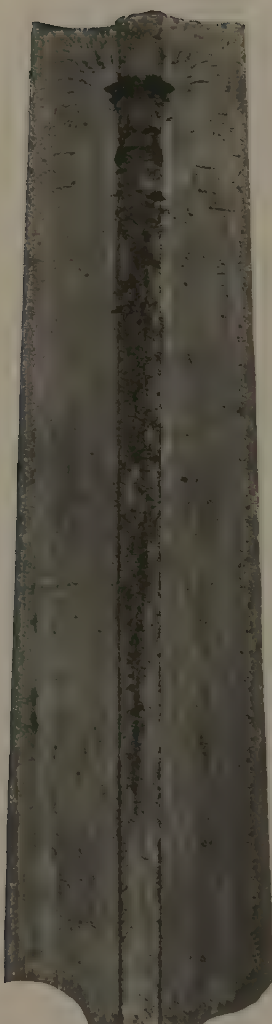
Any substance having a strong affinity for oxygen at high temperatures, and whose oxide is not gaseous, could be used, but that which produces an oxide capable of being slagged off and separated by gravitation would be preferred. The elements generally used for this purpose are silicon, aluminum and titanium.

The action of a deoxidizer in ingots of ordinary rising steel is shown by a study of the photographs of the two split ingots from a low carbon Bessemer heat which are shown on Plates IV and V. Both of the ingots are from the same heat and differ in treatment only in the amount of ferrosilicon which was added in the mold, and the part of the ingot to which it was added. The steel boiled in the mold, and when ingot No. 3 was about half teemed there was a marked evolution of gas which caused it to rise rapidly. This rising took place to such an extent that when about three-fourths of the ingot had been teemed the steel had frothed up nearly to the top. The addition of a very small amount of 50 per cent. ferrosilicon which had been finely ground, caused the steel to subside rapidly, leaving only a thin shell on the outer walls, which showed the height to which the steel had risen. The effect of this small addition extended a little more than half way down the ingot, the portion not affected being plainly marked by a zone of peripheral blow-holes fairly close to surface. The upper portion which solidified simultaneously with the zone containing the peripheral blow-holes is quite solid. Under normal conditions blow-holes will occur in the upper portion of the ingot to a greater degree than the lower, due to the greater ferrostatic pressure in the lower part of the ingot discouraging the evolution of gas, just as the carbonic acid in a bottle of soda water, which is held in solution when under pressure, but is given off when the pressure is reduced. The prevention of peripheral blow-holes in the upper portion by the action of the ferrosilicon is therefore the more marked because the natural tendency is exactly reversed. Deeper in from the surface

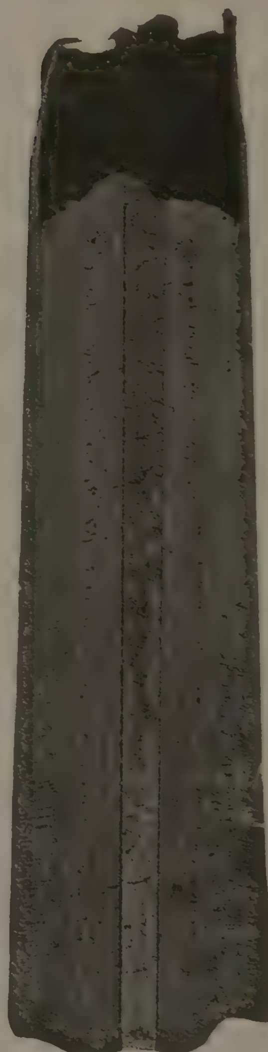
of this ingot there is a line of blow-holes which are caused by the evolution of gas from the steel later on in the cooling history of the ingot, after the effect of the small amount of ferrosilicon has been dissipated, and in this line of blow-holes the normal tendency of the gas bubbles to become smaller and less numerous as the ferrostatic pressure increases is clearly shown. In this ingot there is no sign of a shrinkage cavity or pipe.

In ingot No. 2 four pounds of ground ferrosilicon were added gradually as the teeming proceeded. This was sufficient to almost entirely prevent the evolution of gas, as no blow-holes are present, except in the extreme top of the ingot where the pressure was so low that the small amount of gas in solution was sufficient to overcome it and permit the bubbles to form. The absence of the gas bubbles has caused such a shrinkage in the space occupied by the interior metal that we have very strongly marked piping extending as is sometimes the case in "killed" soft steel, nearly the entire length of the ingot. This tendency may be due to the soft steel, because of its higher melting point, becoming pasty at a much higher temperature than steels of higher carbon, and the increased shrinkage through the greater temperature range tearing apart the pasty steel in the axis of the ingot, which at that temperature has very low tensile strength.

To show the extent of the segregation of the impurities in these two ingots the distribution of the phosphorus has been plotted. In ingot No. 3 the peripheral blow-holes around the lower half have retarded the cooling of that portion, so that a pool of molten metal has existed after the central part above the protecting blow-holes has frozen. This is indicated by the local segregation in the lower part of the ingot where the degree of enrichment is nearly as great as in the larger segregated area at the normal location in the upper part of the ingot. It is also noteworthy that there is a decided difference in the degree of the enrichment of the two sides of the ingot, the portion extending along the line of interior blow-



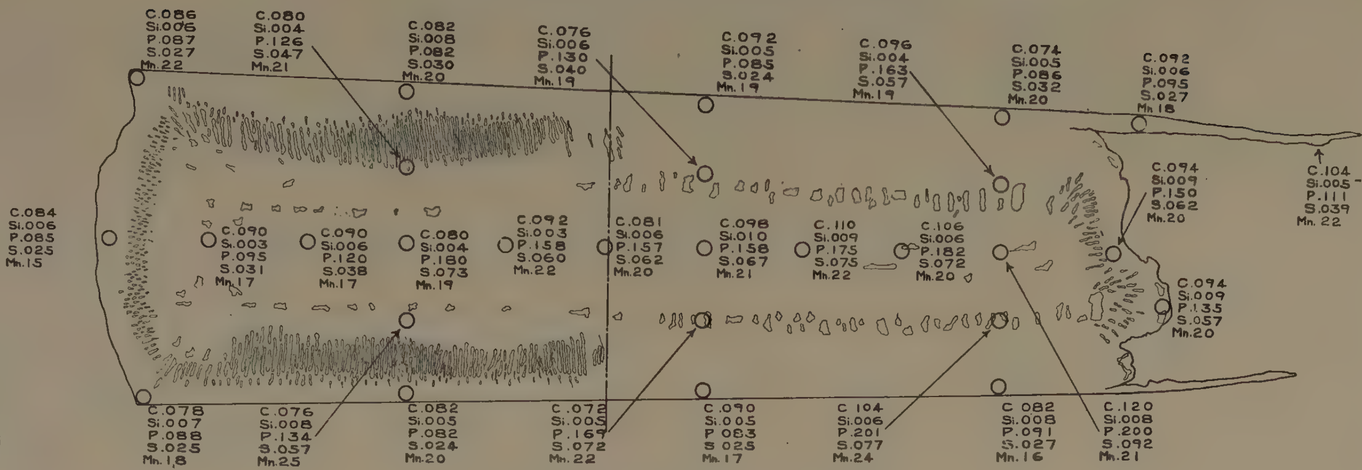
BLOW NO. 12749, INGOT NO. 2.



BLOW NO. 12749, INGOT NO. 3.

INGOT NO.3.

BESSEMER BLOW NO.12749: BLOWN 17 MINUTES: RECEIVER METAL 29500 LBS., FERRO-MANGANESE 150LBS: DATE 2-5-1911. WHEN ABOUT HALF TEEMED AN ACTIVE BOIL TOOK PLACE CAUSING STEEL TO RISE TO TOP OF MOLD WHICH SUBSIDED, AS PER DRAWING, ON THE ADDITION OF ABOUT ONE QUARTER POUND OF FERRO-SILICON: COOLED IN UPRIGHT POSITION.
AVERAGE OF ALL ANALYSES- C.089 Si.006 P.128 S.048 Mn.20
LADLE ANALYSIS- C.080 S 036 Mn.12



Distribution of Phosphorus—.082 to .201
Average Analysis—C.089 P.128 S.048 Mn.20

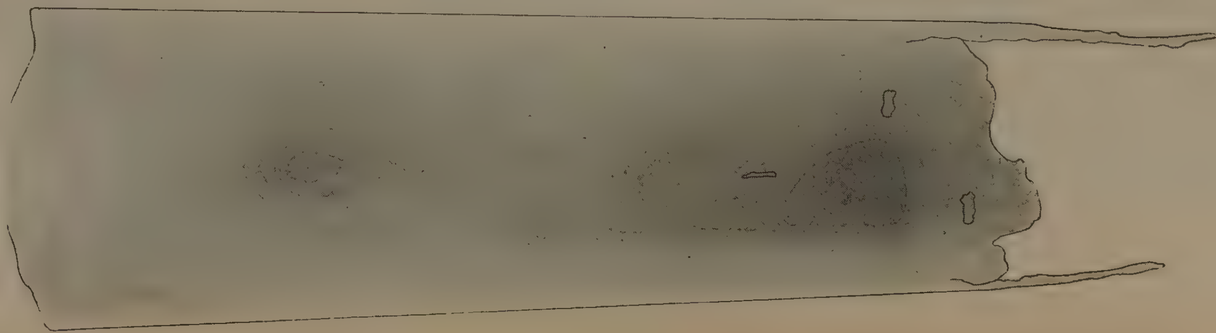
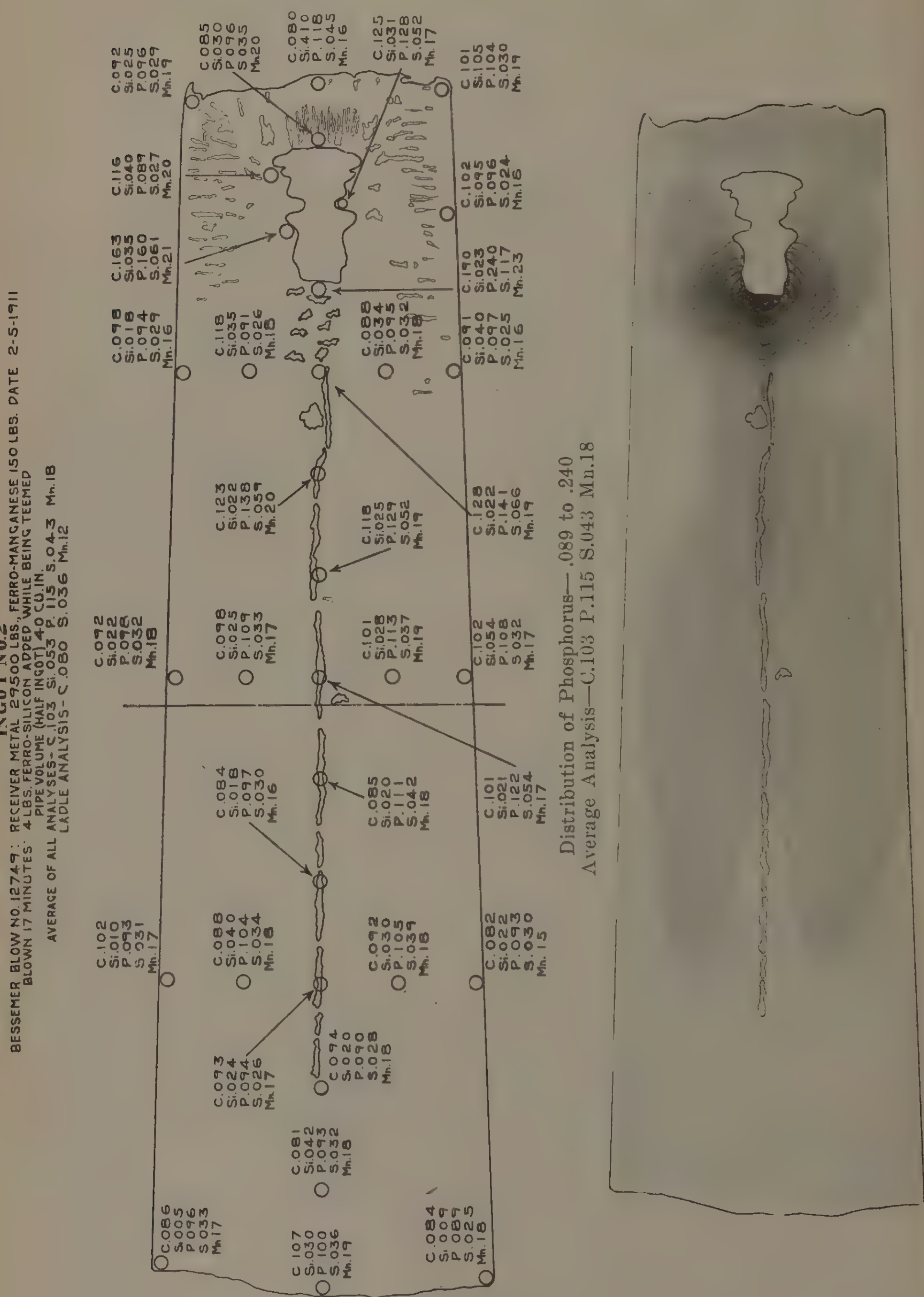


PLATE IV



Distribution of Phosphorus—.089 to .240
Average Analysis—C.103 P.115 S.043 Mn.18

PLATE V

holes on the right-hand side of the illustration being much more highly segregated than the corresponding location on the left side. The protuberance on top of the ingot immediately over this line of blow-holes points the reason for the peculiarity. This protuberance is the growth caused by the metal brought up by the current of gas bubbles and shows that the principal ascending current of gas bubbles was located at this point.

The phosphorus chart of the second ingot indicates that there was very little segregation except at the base of the pipe cavity, where it is strongly marked. This ingot lay very quiet in the mold, and there were no considerable amounts of gas evolved. It is probable that the local enrichment was principally due to the low specific gravity of the segregate (which is squeezed out by the growth of crystals of purer metal further down the ingot) causing it to rise.

The enriched portion in this ingot is well localized, being confined almost entirely in the small pool of metal around the bottom of the main pipe cavity.

The addition of deoxidizers to the steel in the mold, as carried out in these experiments, is not recommended practice, but is used only as a convenient illustration of the action of such deoxidation.

It is preferable to have all reactions completed before the steel is teemed. As far as possible, deoxidation should be carried out in the furnace. It is not always practicable to complete it at this point, and further deoxidation in the ladle is not objectionable, but the least desirable point in the practice of making and pouring steel, to add such deoxidizers, is in the ingot molds, as the non-metallic products of the reaction do not have the same opportunity to separate from the metal as in the furnace or the ladle.

Piping.

Care in making and pouring the steel and thorough deoxidation can be depended on to minimize segregation

to such a degree as to remove all apprehension as to any serious detriment due to it, but in carrying out these remedies in connection with the ordinary practice, we have introduced an element which is just as objectionable. This is the internal shrinkage cavity or "pipe." This much misused word properly applies to the cavity left in the interior of a casting or ingot by reason of the cold metal occupying less space than the same amount of metal while hot, and the shape and size of the cavity will be dependent on the shape of the ingot, the temperature and speed of casting and the relative speed of cooling of the various parts. While various types of special ingots are used for special work, there seems to be one general type which is in almost universal use in the large steel plants. Probably 98 per cent. of the steel made in the United States today is cast into ingots of one general shape. These ingots have a taper of about ¼″ to ½″ per foot of length, the top being materially smaller in section than the base. The ingot mold walls are made heavy to quickly absorb the heat from the ingot and cause it to freeze rapidly, and the solidification proceeds with fair uniformity over the part of the exterior of the ingot which is in contact with the heavy metal walls. If the cooling were absolutely uniform, the last metal to freeze would be toward the bottom where the ingot has the maximum section, but the lesser density of the hotter metal causes it to rise and thus interferes with the absolutely uniform freezing of the exterior walls of the ingot, so that ordinarily the last portion to freeze is toward the upper end. This cooling of the upper portion last, however, is in spite of the taper of the ingot, and too frequently the effect of the taper and the tendency of the hottest metal to seek the top of the freezing ingot interfere with one another to such an extent that the freezing metal bridges from one side to the other, and prevents the lighter portions of the molten metal from rising to the top. A pool of molten metal below such a bridge acts as a center of shrinkage and segregation. As it cools and

solidifies, it shrinks and, its volume being less, a shrinkage cavity results. The bridge very effectually prevents the void being filled by liquid metal from above, and we have a pipe existing at a point where no well behaved pipe should be, so far down the ingot that ordinary discard would not remove it. This has already been referred to in connection with ingot No. 4 on Plate III. The pipe is about 50 per cent. from the top of the ingot, and analyses show that there is marked segregation of impurities in the neighborhood. Both of these features are due to the bridging of the metal above and the formation of a separate pool during the freezing of the ingot.

Unfortunately, this is not an infrequent occurrence; the tendency is always present in an ingot which tapers toward the top, and even where actual piping does not develop there is frequently present a loose spongy structure which, in the opinion of the writer, is responsible for many of the unexplained failures of steel in service.

Even where bridging has not developed sufficiently to break the interior of the ingot into separate pools, the tendency of the upward tapering ingot to pipe deeply is so marked that any effort on the part of the steel maker to thoroughly deoxidize his heats results in such deep piping, and therefore necessity for so much top crop, that the practice is regarded as not being commercial. This effect of the taper of the ingot on the depth of the pipe is very clearly seen by comparing ingots No. 2 and No. 4 on Plate VI. Both of these ingots were cast from the same heat, which was of strongly piping character, and were subjected to identical conditions so that the only variable is the shape of the ingot. The taper is the same in both, but in one case the top is small, and in the other the top is larger. In the first case the pipe cavity extends 28.6 per cent. from the top, and in the other 58.4 per cent. In the one case 71.4 of the ingot is available for product, while in the other little more than half of that amount or 41.6 per cent. is product.

The inverted ingot is highly efficient in preventing the

occurrence of irregularly located pipes and segregated areas. In that type of ingot, the solidification is always progressive from the bottom upwards; the last metal to freeze is always at the upper portion of the ingot, and bridging is practically eliminated. Consequently, when we crop off all the piped portion from the top we can feel assured that we have left only solid steel. Such assurance we never have or can have with the upward tapering ingot. The difficulty with the large topped ingot is that its greater top section means a greater amount of metal discarded for each inch of depth to which the pipe extends, and yet such greater section is what has insured us the progressive upward solidification which is so essential.

To avoid this heavy discard there must be provided some method of keeping a small body of metal at the top of the ingot fluid until all the lower portion has solidified. For this purpose many expedients have been suggested, which are of two general classes:

1—Means for adding heat.

2—Means for conserving the heat already in the molten steel.

Under the first head the following methods have been used:

a—Application of electrically generated heat to the top of the ingot.

b—Application of heat from gas or oil burners to top of ingot.

c—Addition of carbonaceous material, such as coke, charcoal, etc., to top of ingot. This fuel is ignited by the heat of the metal. In some cases a blast of air is used to assist in the combustion of the fuel.

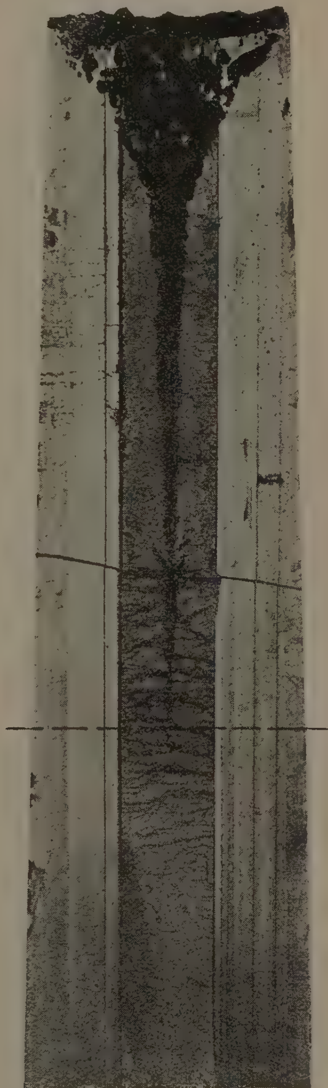
The second means comprises the use of tops made of heat insulating material placed on the ingot molds and filled with the molten metal. Because of the non-conducting character of the top, the metal enclosed is kept fluid longer than that in the body of the ingot.

It is quite evident that the efficiency of the non-con-

Ingot No. 2
No Sink Head

Discard = 28.6%
Product = 71.4%

Ingot No. 4
Standard Ingot
No Sink Head

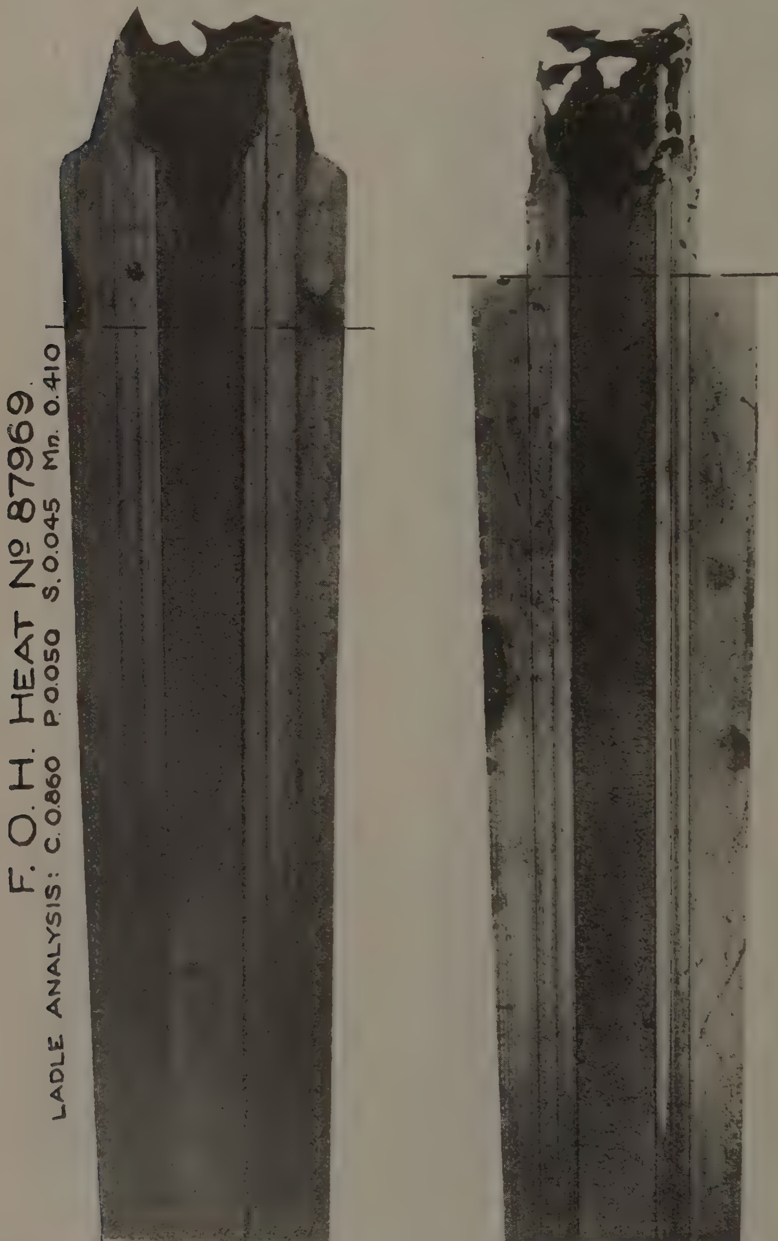


Discard = 58.4%
Product = 41.6%

PLATE VI A

INGOT No. 1
ORDINARY FIRE BRICK
SINK HEAD

INGOT No. 3
SPECIAL SINK HEAD



Discard = 15.3%
Product = 84.7%

Discard = 5.96%
Product = 94.0%

PLATE VI B

ducting top will determine whether or not external heat is necessary. If a top can be obtained which will keep metal molten within it, until all the ingot below the sink-head has congealed, there is evidently no necessity of applying heat. The material which has been most commonly used in the making of non-conducting ingot mold tops is fire-brick. Because of the comparative fragility and the conductivity of this material, these sink-head bricks have been made heavy. Bricks made with an admixture of sawdust or similar material which would be destroyed in the burning, leaving voids scattered through the mass to reduce conductivity, would probably be more efficient, but the reduced strength of the resulting brick would probably necessitate making the bricks even heavier than those ordinarily used. Tops of thin metal have been tried, but the heat loss is so great that no appreciable effect is produced. The writer has used a top composed of a metal casing inclosing a thin lining of dried loam. The loam is rammed into position while moist, is easily and quickly dried, the elimination of the moisture leaving the loam in a very porous condition. The conductivity of this dried loam is so slight that the bare hand can be held on the exterior of a 2½″ casing on an ingot, while a 5″ fire-clay brick is so hot that it will burn the hand. The comparative effect of brick and loam tops is shown by comparing ingots No. 1 and No. 3 on Plate VI. The thickness of the frozen metal in contact with the non-conducting material is much greater in No. 1 than in No. 3. In the latter there is only a thin shell of metal which has formed, the remainder of the metal in the sink-head remaining liquid and feeding into the ingot as shrinkage proceeded. In ingot No. 1 the more rapid conduction of heat through the brick has resulted in a fairly heavy wall forming in contact with the fire-brick, and this metal is entirely unavailable for feeding the shrinkage cavity forming in the ingot. In ingot No. 3 the pipe cavity has been entirely contained in the sink-head portion instead of extending down into the ingot,

as has been the case with the brick top. The difference in the conservation of the heat was such that a much larger volume of metal in the brick sink-head would be necessary to insure all of the body of the ingot being free from pipe.

With the very efficient heat insulation obtained with dry loam, it has been found unnecessary to apply heat to keep the metal in the sink-head molten.

Some of these various means of keeping ingot tops molten have been in restricted use for many years, but in their use the ingots have been allowed to become cold. For special purposes where the product carried a high price, the heavy cost due to allowing the ingot to become cold, then cutting off the sink-head and reheating the cold ingot before working it into product could be absorbed, but such practice was out of the question for any except high-priced steel. The actual cost of doing the work and the cost of fuel were only a part of the penalty, as the reheating of ingots of high-carbon steels involves a considerable risk unless care is taken to apply the heat gradually.

The writer has been experimenting for some years in the effort to develop some practical means of applying the benefits of the sink-head to the ordinary methods of steel-making in commercial use. The principal essentials seem to be:

1—That the ingot be carried through the heating and rolling operations without the necessity of becoming cold.

2—That sink-heads be of such type that ingots of varying weights can be cast from the same ingot molds.

1—To get the solidity desired it is not necessary that the ingots become cold. There is little to be gained by carrying the temperature of the ingot through the range between the solidification point and atmospheric temperatures, and there are very decided objections to it, chiefly the loss of heat, and cost of replenishing it, and the risk of damage to the ingot in reheating. Any betterment in

quality obtained in allowing steel to become cold and then reheating through the critical range is much more economically and safely accomplished after the steel is in the form of a bloom.

The function of the sink-head being the preservation of a reservoir of molten metal on top of the ingot until all the body of the ingot has solidified, it follows that the non-conducting jacket should be kept on the top of the ingot when it is charged hot into the pits. The temperature of the soaking pits is lower than the freezing point of the steel, and there would consequently be a loss of heat from the sink-head even in the pits if there were no protecting jacket. The loss would be much less rapid than in an atmosphere at lower temperature, but the very fact that the ingots solidify throughout while in the pits shows that there is a considerable loss of heat from the molten metal. The proper thermal treatment of high carbon heats involves the use of comparatively cool soaking pits when the ingots are charged. It would be quite possible for the small mass of molten metal comprising the sink-head, if unprotected, to lose heat to such an extent that it would solidify before the greater volume of the ingot. The value of the sink-head in this event is gone, as on the further contraction of the liquid metal in the ingot there could be no feeding from the sink-head which had solidified.

Any large masses of slag-making material are objectionable in the furnaces because of the extra labor involved in keeping the pits clean, and therefore sink-heads of ordinary fire-brick are not as available for use with ingots which are to be handled hot as for ingots which are allowed to become cold. It is true that the ordinary brick tops can be broken off before the ingots are charged, but this involves an additional operation; is objectionable on account of the dirt produced, and, in addition, leaves the sink-heads without protection in the pits. Moreover, it must not be done until immediately before the ingot is charged, as the sink-head cools very

rapidly in the air as soon as the covering is removed. If for any unforeseen reason the charging is delayed after such removal, the value of the sink-head is destroyed, and the ingot will be piped.

This loam used by the writer does not have to be removed from the ingot before the latter is charged into the pit furnaces, but can be allowed to remain on until the ingot is bloomed, being so plastic that it does not affect the rolling. The practice used in connection with these sink-heads is as follows: A wooden form of the dimensions of the sink-head extension desired is placed inside the metal sink-head casing, leaving a space 2½" wide between the form and the casting. This space is filled with moist loam well rammed. The loam and casing are then dried, the drying requiring about two or three hours in a pit oven. A number of wooden pegs around the bottom of the casing prevent the loam lining from slipping from the casing, while the whole is being handled and set on the ingot molds, and the steel is poured in the usual manner. When the metal reaches the sink-head, the wooden pegs are burned off, releasing the iron casing, so that it can be removed, leaving the loam lining attached to and protecting the sink-head against heat loss. The iron castings do not leave the open hearth, being promptly removed and rerammed with fresh loam. The loam lining remains on the ingot until it is rolled, which insures against trouble which would result from delays in charging after the protective covering was removed, or the necessity of banking steel, or any of the many possibilities of commercial steel works' practice, which interfere with the regular routine. In practice, this type of sink-head, besides being more efficient thermally, has been found much cheaper than the regulation brick, and, as stated above, has possibilities which make it much more applicable to ordinary steel works' practice.

In addition to the quality betterments which are possible by the use of inverted ingots with sink-heads, there is possible a very great economy because of the much

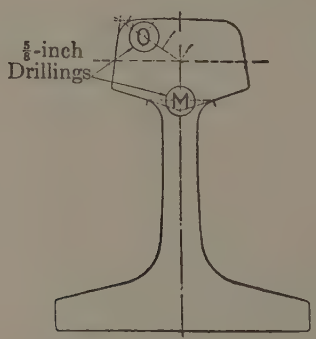
smaller percentage of metal which has to be cropped from the top, as compared with the cropping which is necessary with the ordinary ingot. This is shown in Plate VI. Here are the photographs of four ingots, all poured from the same heat of steel under identical conditions. All were allowed to become cold, and were then slotted about one-third of the way through from either side and broken with wedges. 4 is an ingot of the ordinary shape; 2, an inverted ingot; 1, a similar inverted ingot which was equipped with an ordinary fire-clay sink-head, and 3, a similar ingot equipped with the special sink-head consisting of an iron shell with dried loam lining. The brick sink-head has not been as large or efficient as desirable, but even it shows marked improvement in the resulting percentage of yield over the plain inverted ingot, and gives several times the yield obtained on the plain ingot. (The steel used in these ingots was thoroughly deoxidized steel, and it approaches the conditions shown as it cools.)

2—The value of the sink-head in getting a large percentage of solid steel from the ingot will be materially reduced unless we can regulate the size of the ingot to produce the amount of metal needed. In ordinary practice today this is easily accomplished by pouring the steel to any desired height in the molds. For instance, in most works producing rails, a single size of ingot mold is used, and ingots to economically produce any weight of rails are cast in the same mold. For 90-pound rails only about nine-tenths of the amount of metal is poured into a mold which would be poured if the same number of 100-pound rails were required. Similarly in other products, the weight of the ingot is varied to give the amount of steel required for a given product. Practically all sink-heads used in the past have been so designed that they were set at the top of the ingot mold, and no variation in the weight of the ingot was possible with a given mold. This feature would necessitate an extraordinarily large equipment of molds of various sizes, or else result in the scrapping of considerable quantities of steel. Both of

the difficulties will be avoided by the use of a sink-head which can be set at any desirable height in the ingot mold in accordance with the amount of metal required in the ingot for the particular purpose in view.

This adjustable feature has been tried out in connection with the dried loam sink-heads, and is quite practicable. Several thousand tons of rail ingots have been cast with sink-heads which embodied this feature, the ingots being cast 7 inches shorter than the molds, thereby making a very considerable saving in the scrap loss.

It is practicable to provide for the conservation of the greater part of the original heat and the adjustability of the size of the ingots in connection with inverted ingots equipped with sink-heads, and there seems to be no reason why practically all of the piping steels could not be cast in ingots of this type without incurring excessive costs. For some years the writer has believed that this was possible, and his studies have been directed to that end.



An example of the possibilities in the making of uniform steel in a commercial way is available in the recent rollings of rails for the Pennsylvania Railroad. In 1914 the Pennsylvania issued specifications for steel rails which contained features radically different from any previously published. The most noteworthy of these was a series of tests to determine the degree of segregation as exemplified by carbon. The specifications required drillings for analysis to be taken from two points;

one representing the outside of the head, and the other the junction of the web and head, of a section of rail cut near the top end of the top rail. The content of carbon, phosphorus, silicon and manganese found at the first named point, marked O on the diagram, was required to be entirely within the limits specified, and failure to meet this requirement in regard to any one of the elements named rejected the entire heat. If the analysis of the drillings taken from A was found to meet the requirements, drillings from the point marked M on the diagram were analyzed for carbon, and if the carbon content found varied by more than 12 per cent. from that found at O, all the top rails from that heat were rejected. Similar analyses were made of drillings from the point M on a section cut from the B rail to determine the acceptance or rejection of all rails, and in the event of the rejection of all the B rails, similar tests were made from sections representing the C rails. The failure of the C rail sample rejected the entire heat.

The point O was supposed to be fairly representative of the average of the heat, and the point M, while not being the center of the section nor the point of maximum segregation, was sufficiently near the segregation center to indicate the presence of any strongly marked irregularity in carbon content due to liquation.

The degree of segregation permitted was rather small. The carbon limits prescribed by the specification being .60 per cent. to 75 per cent., the variation permitted amounted to .072 per cent. at the low limit and .090 per cent. at the high. In good routine work, determination by combustion made by two different chemists may vary .02 per cent. Closer work is possible where repeated checks may be run, but this is not practicable where the results must be reported promptly. In a rail mill it is not practicable to hold the rails pending extensive checking, because the mill would be blocked. This variation of .02 per cent. when considered as being possible in either direction, and at either end of the chemical limits, meant

that under a possible combination of conditions there might be available for actual segregation only .032 per cent at low limit and .050 per cent. at the high. The specifications were afterward amended to allow a tolerance of .02 per cent. to cover this possibility of variation in chemists' work in the event of one chemist obtaining results within the limits and the other outside.

These limits were very close, and rails which would meet such conditions would undoubtedly be very different from a large portion of the rails accepted under the specifications in common use. To meet the prescribed tests it was generally proposed to discard sufficient of the upper portion of the ingot to insure that the portion used be uniform within the limits required. Different steelmakers estimated that from 25 to 40 per cent. of the ordinary rail ingot would have to be cropped.

Trials of the new specifications were made at two well-known rail mills and resulted in the rejection of considerable percentages of the rails rolled, but no large discards were made from the tops of ingots. The writer suggested that the requirements of the specification could be met more economically by making use of inverted ingots equipped with sink-heads, which would permit the use of steel which by reason of its being thoroughly deoxidized would show little segregation. Such steel could not be safely cast in the type of ingots ordinarily used for rail steel, because of excessive piping, and because, as explained previously, the location of the piping cannot be predicted with any degree of certainty.

The results of the different efforts to meet the specifications in various ways are given in the following table:

PERCENTAGE OF RAILS REJECTED.

Cause.	ORDINARY INGOTS.				SINK-HEAD INGOTS.		
	Mill A 1st Roll. 1.	Mill A 2d Roll. 2.	Mill B 1st Roll. 3.	Mill B 2d Roll. 4.	Mill B 1st Roll. 5.	Mill B 2d Roll. 6.	Mill B 3d Roll. 7.
Piping	5.30	3.28	4.86	6.26	12.09	8.52	1.76
Drop test breakage	4.54	1.27	0.24	1.17	0.00	0.60	0.00
Segregation	8.84	16.52	11.40	7.40	0.00	0.00	1.04
A. O. analysis	20.80	19.81	12.30	3.24	0.00	5.51	0.00
Total rejections on test	39.48	40.88	28.70	18.07	12.09	14.63	2.80

Column 1 gives the results obtained on Mill A using their ordinary practice of steel-making and discard. Column 2 covers the second rolling at the same mill.

Column 3 shows the results of the first rolling at Mill B, and 4, the second rolling at Mill B, using a somewhat different practice.

Columns Nos. 5, 6 and 7 cover the different rollings to meet the specification, using inverted ingots equipped with sink-heads.

The two earlier rollings of the sink-head series were made from ingots equipped with sink-heads too small to insure all the piping being included in the sink-head. These small sink-heads were gradually replaced by larger ones, and in the last rolling most of the sink-heads were of the proper size.

Piping.

The gradual reduction in the percentage of piped rails as the smaller sink-heads were replaced is clearly shown. The design of the small sink-heads was determined by experiment; the ingots were allowed to become cold and were then split. The small sink-head was ample to protect the ingots under these conditions, but in actual working conditions under which the ingots were stripped and charged into the soaking pits while some of the interior metal was molten, we found that the expansion of the outer walls of the ingot when heated seemed to increase the capacity of the ingot and required more metal in the sink-head. Measurements on a considerable number of $20 \times 23''$ ingots before charging and after being heated, showed an average increase in diameter of 0.3″, corresponding to an increase in volume of about 2.5 per cent. There is no doubt that with a sink-head of proper size, there will be no question as to the piped rails being entirely eliminated.

Segregation.

These specifications are admirably adapted to detect and penalize segregation. Not only the direct check on

segregation in the requirement that the carbon at the point M shall not vary more than 12 per cent. from that at O, but the indirect check on segregation which results from such a severe penalty for the O analysis falling outside the specification requirements. In ordinary commercial ingots, in addition to an enrichment of the metal at the upper central part, there is generally an impoverishment in the segregating elements along the exterior near the top. The only guide the rail mill has as to the grade of steel in a heat is the ladle analysis. This ordinarily is a fair average of the heat, and if the analysis at the point O corresponds to the ladle analysis, the mill can safely apply steel based on the ladle. If, however, the O analysis does not agree with the ladle, rejection of the entire heat is likely to occur in spite of the ladle analysis being well within the requirements. In thoroughly deoxidized steel the O analysis agrees very closely with the ladle, as there is neither the central enrichment nor the exterior impoverishment. In the results of the early rollings shown in columns 1, 2 and 3, the rejections because of O analyses being outside the limits are greater than those due to segregation at the point M.

Chemical Analyses.

The main feature of this specification centered around the chemical analyses, and in these experimental rollings, in order to determine whether or not such a specification was workable, a long series of chemical check work was done jointly by the railroad and the steel works' chemists. A special laboratory was fitted up at the works, and the railroad chemists made their analyses concurrently with the working of the mill, and every determination was checked within .02 per cent. in carbon before the final figures were reported. Similar close checking of the other elements was required. The actual results obtained by the two sets of chemists on each analysis made on the sink-head rails are given in the table attached. This is given simply as an example of the close results which can

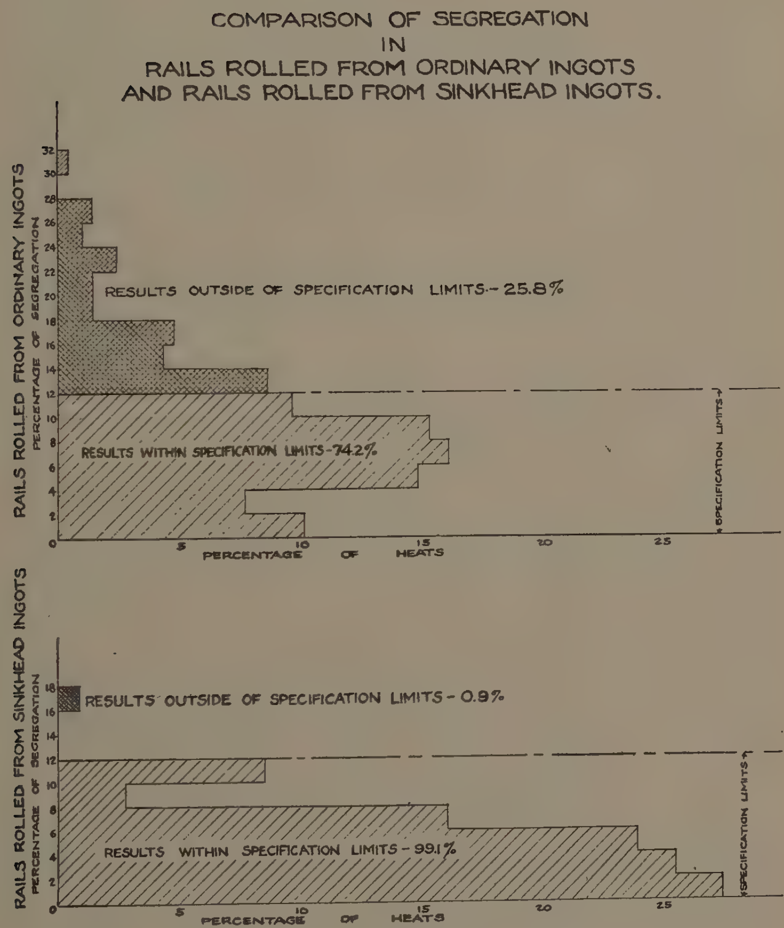

COMPARISON OF SEGREGATION
IN
RAILS ROLLED FROM ORDINARY INGOTS
AND RAILS ROLLED FROM SINKHEAD INGOTS.
RAILS ROLLED FROM ORDINARY INGOTS
PERCENTAGE OF SEGREGATION
RESULTS OUTSIDE OF SPECIFICATION LIMITS - 25.8%
RESULTS WITHIN SPECIFICATION LIMITS - 74.2%
SPECIFICATION LIMITS
PERCENTAGE OF HEATS
RAILS ROLLED FROM SINKHEAD INGOTS
PERCENTAGE OF SEGREGATION
RESULTS OUTSIDE OF SPECIFICATION LIMITS - 0.9%
RESULTS WITHIN SPECIFICATION LIMITS - 99.1%
SPECIFICATION LIMITS
PERCENTAGE OF HEATS

PLATE VII

CHECK ANALYSES ON RAILS ROLLED FROM SINK-HEAD INGOTS.
Analyses marked "C" made by Cambria chemists; those marked "P. R. R." by Pennsylvania chemists.

		Analyses at point O of A Rail			CARBON DETERMINATIONS.								
					A Rail			B Rail			C Rail		
Heat.		Si.	P.	Mn.	O.	M.	% Seg.	O.	M.	% Seg.	O.	M.	% Seg.
90,797	C.	.198	.029	.74	.750	.778	3.73	.740	.770	4.06	.770	.750	—2.59
	P. R. R.	.193	.027	.75	.754	.794	5.31	.761	.784	3.02	.769	.760	—1.16
91,041	C.	.124	.023	.65	.684	.756	10.52	.674	.676	0.30	.696	.660	—5.17
	P. R. R.	.138	.021	.63	.698	.773	10.73	.687	.673	—2.04	.671	.662	—1.34
91,058	C.	.136	.040	.72	.668	.672	0.60	.686	.690	—0.59	.680	.690	1.48
	P. R. R.	.150	.038	.70	.667	.676	1.35	.701	.709	1.15	.703	.710	1.00
91,075	C.	.225	.029	.83	.738	.745	0.96	.746	.730	—2.15	.754	.744	—1.33
	P. R. R.	.203	.028	.79	.738	.753	2.03	.736	.725	—1.50	.742	.734	—1.08
91,105	C.	.135	.028	.74	.727	.700	—3.71	.700	.675	—3.56	.700	.690	—1.42
	P. R. R.	.141	.025	.76	.738	.689	—6.64	.710	.669	—5.77	.687	.698	1.60
91,126	C.	.099	.019	.60	.676	.698	3.26	.666	.664	0.30	.668	.650	—2.69
	P. R. R.	.094	.020	.61	.689	.675	—2.03	.680	.667	—1.91	.667	.636	—4.65
91,139	C.	.078	.020	.74	.640	.640	0	.620	.620	0	.646	.600	—7.11
	P. R. R.	.077	.020	.71	.638	.636	—0.31	.627	.596	—4.94	.640	.605	—5.47
91,182	C.	.142	.023	.77	.670	.700	4.48	.678	.694	2.38	.676	.708	4.75
	P. R. R.	.165	.021	.82	.639	.671	5.01	.658	.683	3.80	.684	.686	0.29
91,202	C.	.101	.019	.63	.722	.713	—1.24	.710	.700	—1.41	.700	.700	0
	P. R. R.	.120	.017	.63	.705	.714	1.28	.680	.693	1.91	.680	.691	1.62
91,271	C.	.138	.020	.74	.688	.679	—1.30	.674	.728	8.01	.710	.704	0.84
	P. R. R.	.165	.019	.72	.691	.673	—2.60	.696	.708	1.73	.679	.694	2.21
91,301	C.	.141	.022	.77	.707	.773	9.33	.720	.740	2.78	.734	.714	—2.72
	P. R. R.	.152	.022	.73	.714	.754	5.60	.747	.733	—1.87	.720	.722	0.28
91,319	C.	.133	.024	.70	.661	.708	7.10	.700	.710	1.43	.664	.700	5.42
	P. R. R.	.136	.023	.70	.669	.693	3.58	.678	.681	0.45	.676	.698	3.27
91,371	C.	.125	.022	.69	.667	.713	6.88	.662	.670	1.21	.684	.640	—6.43
	P. R. R.	.130	.022	.67	.671	.707	5.36	.634	.674	6.31	.667	.625	—6.30
91,396	C.	.041	.017	.66	.610	.628	2.95	.614	.638	3.91	.618	.638	3.23
	P. R. R.	.067	.015	.64	.600	.596	0.68	.606	.618	1.97	.595	.631	6.04
91,442	C.	.147	.017	.59	.671	.644	—4.12	.660	.630	—4.54	.660	.610	—7.57
	P. R. R.	.144	.016	.60	.680	.629	—7.50	.669	.634	—5.24	.660	.604	—8.48
91,465	C.	.078	.023	.80	.730	.755	3.43	.760	.740	—2.63	.754	.740	—1.85
	P. R. R.	.080	.023	.76	.744	.760	2.16	.745	.735	—1.34	.733	.735	0.28
91,480	C.	.104	.018	.68	.625	.627	0.32	.628	.620	—1.27	.608	.640	5.28
	P. R. R.	.125	.019	.68	.625	.651	4.16	.658	.643	—2.27	.636	.640	0.63
91,490	C.	.110	.022	.70	.655	.715	9.17	.650	.664	2.17	.650	.646	—0.61
	P. R. R.	.120	.020	.69	.663	.715	7.84	.660	.660	0	.647	.650	—0.47
91,517	C.	.121	.023	.68	.656	.633	—3.50	.660	.660	0	.660	.664	0.61
	P. R. R.	.141	.020	.71	.669	.622	—7.03	.638	.645	1.10	.680	.653	—3.96
91,527	C.	.103	.024	.71	.645	.610	—5.43	.665	.590	—11.28	.650	.600	—7.69
	P. R. R.	.101	.022	.68	.627	.596	—4.94	.681	.605	—11.16	.642	.598	—6.85
91,539	C.	.101	.020	.71	.649	.713	9.87	.660	.710	7.58	.652	.640	—1.82
	P. R. R.	.100	.018	.71	.656	.722	10.70	.682	.720	5.58	.647	.638	1.39
91,551	C.	.151	.024	.75	.698	.723	3.59	.684	.700	2.36	690	.690	0
	P. R. R.	.165	.024	.73	.665	.736	10.68	.688	.671	—2.46	.673	.664	—1.33
91,559	C.	.073	.023	.73	.669	.712	6.42	.646	.650	0.62	.660	.664	0.61
	P. R. R.	.078	.023	.72	.676	.691	2.22	.669	.631	—5.68	.689	.673	—2.32
91,572	C.	.180	.027	.78	.747	.748	0.13	.680	.694	2.07	.680	.660	—2.94
	P. R. R.	.179	.029	.76	.727	.727	0	.660	.676	2.42	.693	.682	—1.58
91,580	C.	.200	.024	.74	.718	.720	7.23	.730	.760	4.11	.746	.760	1.87
	P. R. R.	.193	.023	.77	.732	.784	7.11	.719	.763	6.12	.733	.733	0
91,585	C.	.183	.023	.76	.681	.678	—0.49	.674	.672	—0.30	.680	.688	1.18
	P. R. R.	.188	.024	.72	.667	.665	—0.30	.686	.647	—5.69	.694	.671	—3.31
91,599	C.	.120	.026	.68	.648	.655	1.09	.670	.660	—1.49	.670	.650	—2.80
	P. R. R.	.120	.022	.68	.644	.642	—0.31	.689	.660	—4.21	.664	.651	1.96
91,611	C.	.145	.016	.62	.661	.690	4.49	.688	.690	0.30	.686	.672	—2.03
	P. R. R.	.165	.015	.61	.674	.707	4.90	.665	.676	1.66	.669	.676	1.05
91,625	C.	.140	.019	.71	.691	.753	8.96	.698	.692	—0.86	.688	.698	1.45
	P. R. R.	.162	.018	.70	.693	.749	8.08	.673	.674	0.14	.671	.682	1.64
91,640	C.	.113	.024	.75	.663	.691	4.22	.662	.664	0.39	.680	.684	0.59
	P. R. R.	.125	.026	.73	.687	.670	—2.48	.665	.680	2.26	.665	.680	2.26
91,643	C.	.137	.016	.67	.750	.772	2.92	.760	.778	2.37	.778	.760	—2.32
	P. R. R.	.145	.019	.64	.756	.751	—0.66	.752	.758	0.80	.745	.746	0.14
91,655	C.	.113	.016	.68	.624	.673	7.85	.604	.600	—0.66	.600	.588	—2.00
	P. R. R.	.145	.013	.65	.630	.659	4.60	.614	.596	—2.92	600	.574	—4.32

Heat.		Analyses at point O of A Rail Si.	P.	Mn.	CARBON DETERMINATIONS. A Rail O.	M.	% Seg.	B Rail O.	M.	% Seg.	C Rail O.	M.	% Seg.
91,661	C	.131	.020	.70	.761	.786	3.38	.744	.770	3.48	.740	.737	—0.40
	P. R. R.	.145	.019	.65	.744	.776	4.29	.749	.747	—0.26	.736	.774	5.17
91,666	C	.133	.018	.67	.735	.800	8.84	.748	.757	1.21	.740	.746	0.81
	P. R. R.	.148	.015	.70	.751	.800	6.52	.743	.742	—0.13	.743	.754	1.48
91,680	C	.122	.010	.63	.683	.727	6.44	.714	.730	2.23	.690	.685	—0.72
	P. R. R.	.112	.012	.63	.700	.747	6.70	.709	.727	2.55	.691	.711	2.90
91,710	C	.126	.022	.67	.658	.630	—1.22	.650	.650	0	.630	.646	2.53
	P. R. R.	.127	.023	.62	.633	.645	1.79	.644	.635	—1.40	.622	.629	1.13
91,717	C	.126	.019	.65	.675	.692	2.52	.680	.690	1.47	.686	.700	2.04
	P. R. R.	.112	.018	.65	.664	.685	3.16	.689	.689	0	.682	.685	0.43
91,720	C	.105	.010	.65	.638	.647	1.41	.640	.630	—1.56	.634	.640	0.95
	P. R. R.	.110	.011	.66	.636	.631	—0.78	.616	.649	5.37	.640	.652	0.88
91,739	C	.110	.020	.71	.680	.690	1.48	.680	.680	0	.670	.690	2.98
	P. R. R.	.125	.022	.73	.658	.669	1.68	.675	.694	2.82	.682	.665	—2.49
91,746	C	.136	.015	.69	.694	.685	—1.30	.702	.700	—0.29	.704	.680	—3.41
	P. R. R.	.153	.015	.69	.687	.707	2.61	.705	.709	0.57	.693	.698	0.72
91,760	C	.132	.017	.66	.702	.689	—1.86	.700	.718	2.57	.700	.704	0.57
	P. R. R.	.136	.015	.67	.694	.710	2.31	.694	.707	1.88	.685	.686	0.15
91,790	C	.155	.033	.78	.710	.741	4.37	.740	.782	5.68	.748	.776	3.74
	P. R. R.	.142	.034	.78	.702	.761	8.39	.731	.754	3.15	.729	.747	2.49
91,817	C	.141	.019	.75	.653	.655	0.31	.644	.668	3.73	.650	.660	1.54
	P. R. R.	.133	.021	.70	.662	.633	—4.38	.633	.653	3.17	.665	.658	—1.05
91,075	C	.225	.029	.83	.738	.745	0.96	.746	.730	—2.15	.754	.744	—1.33
	P. R. R.	.203	.028	.79	.738	.753	2.03	.736	.725	—1.50	.742	.734	—1.08
91,093	C	.105	.020	.75	.725	.710	—2.06	.690	.690	0	.710	.680	—4.22
	P. R. R.	.098	.024	.71	.710	.725	2.10	.694	.694	0	.696	.698	0.30
91,139	C	.078	.020	.74	.640	.640	0	.620	.620	0	.646	.600	—7.11
	P. R. R.	.077	.020	.71	.638	.636	—0.31	.627	.596	—4.94	.640	.605	—5.47
91,239	C	.129	.022	.73	.600	.650	8.31	.628	.640	1.90	.620	.630	1.61
	P. R. R.	.139	.020	.73	.593	.660	11.13	.641	.643	0.30	.623	.624	0.15
91,551	C	.151	.024	.75	.698	.723	3.59	.684	.700	2.36	.690	.690	0
	P. R. R.	.165	.024	.73	.665	.736	10.68	.688	.671	—2.46	.673	.664	—1.33
91,572	C	.180	.027	.78	.747	.748	0.13	.680	.694	2.07	.680	.660	—2.94
	P. R. R.	.179	.029	.76	.727	.727	0	.660	.676	2.42	.693	.682	—1.58
91,580	C	.200	.024	.74	.718	.720	7.23	.730	.760	4.11	.746	.760	1.87
	P. R. R.	.193	.023	.77	.732	.784	7.11	.719	.763	6.12	.733	.733	0
91,585	C	.183	.023	.76	.681	.678	—0.49	.674	.672	—0.30	.680	.688	1.18
	P. R. R.	.188	.024	.72	.667	.665	—0.30	.686	.647	—5.69	.694	.671	—3.31
91,640	C	.113	.024	.75	.663	.691	4.22	.662	.664	0.39	.680	.684	0.59
	P. R. R.	.125	.026	.73	.687	.670	—2.48	.665	.680	2.26	.665	.680	2.26
91,879	C	.162	.027	.84	.690	.700	1.45	.688	.730	6.10	.700	.706	0.86
	P. R. R.	.156	.030	.85	.698	.728	4.30	.719	.734	2.10	.711	.724	1.82
91,894	C	.109	.030	.79	.639	.641	0.32	.642	.652	1.57	.662	.654	—1.20
	P. R. R.	.122	.027	.75	.645	.652	1.09	.654	.650	—0.62	.654	.645	—1.38
91,902	C	.128	.021	.72	.683	.652	—4.53	.670	.660	—1.49	.680	.658	—3.22
	P. R. R.	.128	.018	.72	.676	.683	1.04	.702	.675	—3.84	.660	.678	2.73
91,916	C	.107	.018	.55	.680	.723	6.33	.700	.728	4.00	.668	.685	2.57
	P. R. R.	.114	.019	.55	.693	.729	5.21	.720	.725	0.70	.660	.691	4.70
91,938	C	.131	.018	.72	.649	.679	4.64	.656	.674	2.75	.640	.650	1.57
	P. R. R.	.128	.020	.74	.676	.680	0.59	.673	.680	1.04	.669	.671	0.31
91,953	C	.143	.018	.63	.710	.756	6.48	.700	.760	8.57	.700	.700	0
	P. R. R.	.145	.016	.65	.710	.745	4.94	.714	.763	6.87	.714	.690	—3.36
91,973	C	.175	.040	.81	.667	.702	5.25	.680	.694	2.37	.696	.680	—2.39
	P. R. R.	.197	.040	.83	.701	.701	0	.707	.701	—0.85	.700	.700	0
91,997	C	.233	.018	.71	.654	.690	5.50	.654	.684	4.59	.674	.686	1.78
	P. R. R.	.207	.016	.71	.678	.687	1.31	.685	.689	0.59	.673	.674	0.14
92,008	C	.174	.020	.70	.696	.733	5.32	.680	.718	5.58	.676	.664	—1.77
	P. R. R.	.163	.016	.70	.691	.740	7.08	.708	.731	3.27	.711	.667	—6.18
92,031	C	.190	.023	.84	.723	.786	8.71	.748	.740	—1.07	.750	.740	—1.33
	P. R. R.	.172	.021	.84	.744	7.69	3.37	.734	.762	3.83	.742	.740	—0.26
92,060	C	.170	.020	.75	.663	.730	1.01	.682	.684	0.30	.680	.708	4.11
	P. R. R.	.147	.021	.77	.690	.713	3.32	.696	.705	1.30	.671	.682	1.63
92,080	C	.146	.019	.75	.732	.772	5.32	.752	.750	—0.26	.740	.687	—7.16
	P. R. R.	.154	.021	.77	.745	.783	5.08	.753	.770	2.26	.751	.720	—4.13
92,098	C	.114	.014	.63	.638	.694	8.77	.656	.670	2.14	.646	.670	3.72
	P. R. R.	.132	.013	.61	.656	.702	7.02	.662	.669	1.07	.645	.642	—1.46
92,117	C	.126	.026	.71	.709	.725	2.25	.700	.700	0	.720	.706	—1.94
	P. R. R.	.141	.028	.71	.730	.714	—2.19	.729	.713	—2.19	.707	.729	3.10
92,135	C	.142	.017	.64	.720	.755	4.87	.732	.720	—1.64	.730	.720	—1.36
	P. R. R.	.134	.017	.62	.740	.754	1.90	.729	.720	—1.23	.717	.713	—0.56

Heat.		Analyses at point O of A Rail Si.	P.	Mn.	CARBON DETERMINATIONS. A Rail O.	A Rail M.	A Rail % Seg.	B Rail O.	B Rail M.	B Rail % Seg.	C Rail O.	C Rail M.	C Rail % Seg.
92,149	C.	.149	.017	.59	.668	.725	8.51	.698	.666	—4.48	.668	.660	—1.20
	P. R. R.	.160	.016	.59	.702	.744	5.98	.698	.660	—5.44	.685	.656	—4.24
92,172	C.	.098	.018	71	.660	.665	0.76	.672	.664	—1.18	.666	.684	2.70
	P. R. R.	.086	.017	.71	.658	.667	1.37	.667	.665	—0.30	.680	.689	1.32
92,192	C.	.162	.018	.73	.743	.734	—1.22	.746	.720	—3.48	.740	.700	—1.35
	P. R. R.	.153	.020	.74	.749	.744	—0.66	.742	.748	0.81	.754	.749	0.66
92,223	C.	.148	.020	.77	.770	.825	7.13	.770	.780	1.30	.774	.780	0.79
	P. R. R.	.134	.022	.78	.780	.832	6.65	.780	.787	0.90	.776	.780	0.51
92,363	C.	.102	.017	.71	.704	.709	0.71	.690	.712	3.18	.700	.680	—2.86
	P. R. R.	.102	.014	.69	.705	.733	3.98	.678	.707	4.28	.691	.660	—4.49
92,448	C.	.117	.017	.69	.637	.665	2.84	.646	.650	0.62	.632	.617	—2.37
	P. R. R.	.132	.016	.68	.651	.669	2.78	.653	.638	—2.23	.642	.636	—0.93
92,502	C.	.166	.034	.85	.675	.722	6.95	.706	.690	—2.27	.694	.670	—3.46
	P. R. R.	.166	.032	.82	.700	.738	5.41	.692	.683	—1.30	.705	.661	—6.24
92,524	C.	.150	.039	.86	.705	.755	7.10	.720	.730	1.40	.720	.710	—1.39
	P. R. R.	.168	.040	.86	.720	.771	7.08	.726	.760	4.69	.733	.708	—3.68
92,549	C.	.159	.015	.74	.725	.748	3.18	.760	.740	—2.10	.768	.680	—8.11
	P. R. R.	.156	.013	.77	.722	.749	3.73	.761	.758	—2.76	.689	.689	—9.10
92,587	C.	.128	.018	.65	.705	.763	8.21	.682	.712	4.39	.694	.710	2.30
	P. R. R.	.138	.015	.63	.708	.792	11.85	.707	.731	3.39	.693	.682	—1.59
92,639	C.	.168	.020	.74	.733	.741	2.18	.710	.720	1.42	.720	.712	—1.11
	P. R. R.	.153	.018	.79	.745	.740	—0.67	.720	.736	2.23	.738	.713	—3.38
92,659	C.	.086	.017	.66	.655	.698	6.58	.640	.670	4.69	.634	.670	5.68
	P. R. R.	.083	.019	.64	.663	.725	9.37	.665	.660	—0.75	.647	.641	—0.92
92,690	C.	.195	.017	.77	.724	.726	0.30	.714	.700	—1.96	.714	.704	—1.40
	P. R. R.	.190	.020	.76	.732	.760	3.81	.714	.717	0.41	.709	.718	1.28
92,715	C.	.100	.022	.70	.692	.740	6.94	.700	.720	2.86	.690	.700	1.47
	P. R. R.	.117	.020	.69	.714	.760	7.69	.718	.738	2.78	.671	.772	7.61
92,747	C.	.120	.037	.68	.707	.735	3.96	.704	.710	0.85	.714	.700	—1.96
	P. R. R.	.116	.036	.71	.716	.732	3.23	.700	.738	5.42	.701	.690	—1.58
92,775	C.	.150	.029	.82	.717	.765	6.69	.752	.778	3.46	.714	.702	—1.68
	P. R. R.	.141	.032	.86	.733	.770	5.04	.747	.767	2.69	.734	.701	—4.49
92,810	C.	.144	.019	.63	.702	.742	5.69	.684	.720	3.75	.676	.670	—0.89
	P. R. R.	.136	.016	.65	.707	.789	5.92	.698	.742	6.29	.702	.684	—2.56
92,830	C.	.121	.031	.74	.660	.702	6.37	.680	.700	2.91	.686	.670	—2.33
	P. R. R.	.116	.029	.75	.687	.709	3.22	.680	.716	5.30	.696	.691	—0.72
92,881	C.	.079	.017	.75	.665	.660	—0.75	.650	.646	—0.62	.650	.640	—1.54
	P. R. R.	.078	.016	.72	.651	.676	3.80	.645	.651	0.92	.656	.664	1.22
92,911	C.	.182	.021	.75	.748	.787	5.22	.730	.796	9.06	.740	.730	—1.34
	P. R. R.	.179	.023	.77	.756	.800	5.83	.738	.791	8.14	.764	.744	—2.61
92,926	C.	.125	.018	.67	.699	.740	5.88	.702	.710	1.14	.700	.670	—4.29
	P. R. R.	.117	.015	.63	.685	.756	10.38	.715	.716	0.15	.715	.621	—6.16
92,978	C.	.215	.026	.78	.710	.727	3.72	.710	.720	1.41	.720	.700	—2.77
	P. R. R.	.216	.027	.73	.727	.751	3.30	.716	.733	2.38	.718	.720	0.29
92,996	C.	.100	.025	.71	.650	.666	2.48	.646	.640	—0.93	.632	.590	—6.64
	P. R. R.	.105	.027	.74	.668	.685	2.55	.650	.656	0.92	.641	.610	—4.83
93,010	C.	.209	.018	.71	.632	.746	18.04	.676	.700	3.56	.684	.650	—4.96
	P. R. R.	.189	.018	.75	.651	.762	17.04	.685	.724	5.70	.684	.669	—2.18
93,029	C.	.246	.033	.79	.708	.760	7.34	.730	.730	0	.720	.760	5.55
	P. R. R.	.226	.033	.79	.713	.764	7.16	.740	.740	0	.738	.760	2.98
93,078	C.	.151	.022	.70	.669	.667	—0.30	.668	.660	—0.20	.678	.660	—2.65
	P. R. R.	.148	.026	.71	.662	.660	—0.30	.689	.651	—5.52	.694	.674	—2.88
93,096	C.	.119	.030	.61	.683	.715	4.69	.680	.710	4.40	.670	.660	—1.49
	P. R. R.	.098	.030	.61	.705	.723	2.56	.691	.705	2.03	.692	.684	—1.16
93,122	C.	.148	.024	.70	.746	.748	0.28	.740	.756	2.18	.744	.716	—3.76
	P. R. R.	.155	.024	.66	.745	.738	—0.94	.731	.745	1.92	.716	.694	—3.07
93,159	C.	.095	.024	.81	.713	.689	—3.36	.728	.702	—3.56	.716	.680	—5.03
	P. R. R.	.107	.023	.77	.727	.696	—4.26	.702	.698	—0.56	.713	.682	—4.35
93,176	C.	.122	.020	.65	.600	.657	9.50	.600	.630	5.00	.596	.614	3.02
	P. R. R.	.105	.022	.65	.614	.650	5.86	.612	.627	2.47	.616	.610	—0.97
93,214	C.	.125	.022	.62	.665	.681	2.40	.674	.690	2.38	.660	.680	3.02
	P. R. R.	.117	.022	.62	.694	.689	—0.72	.664	.692	4.21	.669	.680	1.64
93,246	C.	.142	.029	.71	.655	.674	2.91	.680	.680	0	.670	.680	1.49
	P. R. R.	.136	.029	.68	.669	.685	2.39	.683	.690	1.03	.690	.685	—0.72
93,280	C.	.164	.027	.73	.735	.797	8.44	.716	.740	3.06	.714	.710	—0.56
	P. R. R.	.144	.022	.76	.753	.800	6.24	.749	.752	0.40	.754	.749	—0.66
93,302	C.	.203	.028	.77	.690	.693	0.44	.680	.680	0	.680	.684	—0.59
	P. R. R.	.179	.027	.80	.714	.709	—0.70	.701	.707	0.87	.689	.685	—0.58
93,339	C.	.128	.025	.75	.695	.767	10.37	.728	.756	3.86	.718	.680	—5.30
	P. R. R.	.120	.024	.79	.716	.789	10.20	.742	.760	2.42	.740	.682	—7.84
93,361	C.	.142	.020	.70	.666	.720	8.12	.680	.670	—1.46	.654	.622	—4.89
	P. R. R.	.136	.018	.72	.680	.751	10.45	.700	.676	—3.42	.684	.634	—7.30
93,438	C.	.183	.023	.68	.689	.662	—3.92	.676	.632	—6.52	.680	.630	—7.35
	P. R. R.	.179	.022	.67	.682	.683	—0.58	.680	.644	—5.33	.687	.656	—4.51
93,451	C.	.141	.018	.61	.706	.650	—7.94	.690	.680	—1.45	.690	.630	—6.99
	P. R. R.	.130	.015	.59	.703	.652	—7.26	.707	.705	—0.28	.689	.644	—6.53
93,467	C.	.134	.031	.83	.735	.748	1.78	.740	.750	1.35	.740	.750	1.35
	P. R. R.	.133	.029	.84	.750	.765	1.02	.743	.770	3.61	.756	.752	—0.53

be obtained even under the stress of the necessity of very rapid work, as the results had to be obtained promptly so as to avoid delays in shipping the rails. Using the railroad chemists' results, which must of necessity be considered decisive, the percentage of segregation which was found in the top rails was 9.29 per cent. for rails rolled from ordinary ingots and 4.31 per cent for rails rolled from sink-head ingots. There is on the average more than twice as much segregation in the ordinary ingots as in the sink-head type. A more detailed comparison is shown on Plate VII, which shows how much more uniform the sink-head ingots were. This diagram shows that 25.4 per cent. of the analyses from heats cast in ordinary ingots were outside the rejection limits while less than 1 per cent. of the analyses from sink-head heats were outside. Out of all the 5,000 tons of rails made from sink-head ingots, we found only one case where the segregation was sufficient to cause rejection, and we have reason to think this was due to an error in not following instructions, and not to anything inherent in the method of producing uniform steel.

By taking a large discard from the top of the ingot, fairly uniform steel can be obtained, but, as stated earlier, this is not economical, nor is it certain, as there are many ingots like Ingot 4 on Plate III, in which there is segregation and a tendency to pipe with sometimes actual piping 50 per cent. or more from the top of the ingot. The Pennsylvania specification will not detect defects of this kind, although it is certain that it will result in a great betterment in the quality of the rails over those purchased under the usual specifications.

These experimental rollings of rails have been selected to show the possibilities of the inverted ingot in making steel commercially which is practically free from segregation, because the testing was so thorough and so well checked by the purchaser that there can be no question as to the results. Equally striking effects have been produced in the making of forging steels where the necessity

of producing sound steel is probably more imperative in a commercial sense than in the rails. A small pipe may exist in a rail and not be detected for years, if ever. In the case of some forgings, crank shafts for instance, a great deal of expensive work may be done by the customer in forging and machining before he cuts out the throw. This operation is likely to disclose even the slightest pipe, and, if such is disclosed, all the work done up to that time is wasted. The buyer of forging blooms can very economically pay a substantial extra for steel which can be guaranteed as sound, and an inverted ingot equipped with an efficient sink-head is the surest way to produce such steel.

In the past the steel-maker has often met exacting requirements by using only the lower portion of the ingot for product demanding what is generally considered exceptional quality, and applying the upper portion in the making of product on which special refinements did not appear to be necessary. Splice bars, tank plates, light rails, etc., were frequently made from the top cuts of ingots, and appeared to give satisfaction, but there is a general demand for better quality all along the line, and it is reaching all these products. The man who formerly bought flange steel whenever his work involved the slightest flanging operation, now orders tank steel and insists on it being capable of flanging; the splice bar, by reason of more severe service conditions and the demand that failures be eliminated, is now subject to stringent testing requirements. In fact, one of the leading railroads has very recently put out a specification for splice bars in which the requirements are as exacting as for the highest class of heat treated forgings. These changes in the requirements of customers are changing the economic conditions in the steel works. If the discard has to be scrapped, a very much smaller discard will bring the cost up to the cost of improved casting practice, than would be true if the discard could be utilized for product, and the gradual and rapid restriction of the uses to which the

upper portions of the standard ingot can be used is forcing more and more of the top cuts into the scrap heap.

Some cheap method must be developed to make a larger portion of the ingot available for the new and exacting requirements, and so certain are the results which have been obtained through the use of the sinkhead that the writer believes some adaptation of it is the most promising means of achieving the desired result. (Applause.)

President Gary: We will now have a brief discussion of Mr. Kenney's paper by Dr. Henry M. Howe, Professor Emeritus of Metallurgy of Columbia University, New York. (Applause.)

THE COMMERCIAL PRODUCTION OF SOUND AND HOMOGENEOUS STEEL

Discussion by Henry M. Howe
Emeritus Professor of Metallurgy, Columbia University, New York City

Let us hope that this discussion will make it well, surely, and publicly known that both those who decide the procedure in rail-making and also their advisers are very keenly alive to their grave responsibility to travelers: that familiarity has not dulled them to the appeal of every victim of a rail breakage to leave no effort unmade to shield others from a death like his; has not clouded their perception that the rail-maker who contributes to a human death by failure to do what lies in him to prevent it by exercising his power, his knowledge, his skill, and his inventive faculty, is to that extent accountable for that death.

The danger to life from the use of our common pyramidal and cold-topped rail ingots has been so long and prominently before us that we turn eagerly to Mr. Kenney's most promising plan for avoiding it.

His reason why wild steel segregates is certainly attractive, the supposed entraining upwards of the metal alongshore, enriched in the segregating elements, and the resultant concentration of those elements in the upper part of the axis. Yet on reflection we do not find this wholly satisfying. This lively movement ought to stir the metal up, to efface rather than to cause local enrichments. The lightness of these elements hardly counts. A spoonful of whiskey, if set skillfully on the surface of a glass of still water, indeed remains in place pretty well. But stir the water ever so little, and the whiskey mixes with it and can never again be parted from it by any mechanical means.

I incline to explain the freedom of quiet steel from

segregating in a radically different way, by its leading to the landlocking type of solidification.

Two Types of Solidification.

We conceive of two extreme types of solidification, the onion type, with the deposition of successive concentric layers one on another, and the landlocking type, by the outshooting of branching pine trees from the shores of the already solid layers. These outshooting pine trees lock between their trunks and branches the residual molten metal, with the result that each little pool thus trapped retains the whole of its carbon, phosphorus and sulphur, and no general migration thence of any part of these elements to an axial last freezing pool is possible. Thus it is easy to understand why this landlocking type of solidification opposes axial segregation.

Quiet leads in two ways to this landlocking.

The first particle of iron which freezes out is much poorer in carbon than the molten metal from which it freezes, and this selection of course makes the shore layer of the remaining molten metal correspondingly richer in carbon than it was before the freezing began, and probably so rich that its freezing point is higher than the existing temperature. As a result, this shore layer cannot freeze, and no additional iron can freeze out of the molten and attach itself to the already formed solid layers till, by the slow process of diffusion, the layer of the molten in contact with them has become so poor in carbon that it can freeze at the existing temperature.

If now we imagine that two pine tree trunks have already formed and are projecting out into the molten, it is evident that this process of diffusion will lower the carbon content of the molten metal in contact with their tips more rapidly than that of the landlocked metal between their trunks, so that their tips will grow faster than their sides. But this is a condition which continuously exaggerates itself. The longer the trunks of the

pine tree are, the more effectually do they shut off the molten metal about their bases from being so impoverished in carbon by diffusion as to become capable of freezing at the existing temperature.

This principle, which thus leads to the rapid growth of the pine tree tips, has already led to the formation of the pine trees themselves. Any slightest protrusion at any one spot on the surface of the solid layers at their contact with the molten, has a corresponding advantage over the concave spaces about it. Because it protrudes, it will the sooner have molten metal against it on which it can feed; that is to say, molten metal poor enough in carbon to be able to freeze at the existing temperature. Hence from being a slight protrusion it grows rapidly into being an outshooting blade. Because it thus grows faster than the concavities beside it, it continuously increases its advantage. To him that hath shall be given.

Quiet Opposes Segregation.

But this advantage which the first incipiency of a protrusion has is in large part lost if the metal is in rapid movement, because this movement feeds the concavities beside the protrusion almost as fast as the protrusion. The advantage which a protrusion has is very great if diffusion alone is to remove the carbon of the shore layer of molten metal which is unfreezeable because too rich in carbon. But if there is violent motion, as in rising steel, this feeds the valleys almost as effectively as the hills, the sides of the pine trees almost as effectively as their tips.

Clearly if solidification is very rapid, as in the case of narrow ingots, or in case the steel is cast so cool that it stores up little heat in the mould walls, or if those walls themselves are so massive that their temperature is raised but little by the heat which they receive from the steel, then the advantage which protrusions have is proportionally greater, especially if the metal is quiet, so

that the supply of freezeable metal has to come through diffusion only. Hence the less segregation under these conditions.

This brings us to a special way in which quiet opposes segregation. Quiet metal often cools far below its true freezing point before freezing actually starts. But once started it goes on with extraordinary rapidity. And this rapidity, by exaggerating the advantage which every incipient protrusion has, leads to great landlocking, and thereby opposes segregation. (Applause.)

President Gary: We will next have a paper on Waste-Heat Boilers for Open-Hearth Furnaces by Mr. Charles J. Bacon, Steam Engineer of the Illinois Steel Company, South Chicago, Illinois.

WASTE-HEAT BOILERS FOR OPEN-HEARTH FURNACES

CHARLES J. BACON
Steam Engineer, Illinois Steel Co., So. Chicago

The employment of boilers for utilizing waste heat from open-hearth and other regenerative furnaces directs attention to a region where steel-makers may find attractive opportunity for enhancing economy. While waste-heat boilers in one form or another have long been used with heating, puddling and other non-regenerative furnaces, only during the last four or five years has the practicability of their use with regenerative furnaces been conclusively demonstrated. The introduction of a boiler in the path of hot gases is not in itself novel, and no mysticism has been unfolded in recent investigations. What has been accomplished, however, is the practical proof of usefulness of boilers with low temperature gases and a determination of the conditions of open-hearth practice that limit the constructive and operative features. Necessarily, a study has been made of the rate of heat transmission existing in commercial types of boilers. The tardiness in the development of boilers for recovering the enormous quantities of waste heat from regenerative furnaces is an indication of the difficulties and uncertainties in the path of this form of improvement, whereas the use of boilers with non-regenerative furnaces has long been common practice.

Existing boilers on large open-hearth furnaces are showing a saving which, when expressed in terms of fuel required in coal-fired boilers, is equivalent to at least 250 pounds of coal (11,000 B.t.u. per pound) per ton of ingots. From statistics of this Institute, the amount of open-hearth steel produced in the year 1913 in the United

States was approximately 27,000,000 gross tons. As the majority of the furnaces are over 50 tons capacity, it may be stated conservatively that the use of boilers would result in saving between 150 and 200 pounds of a medium grade of coal per ton on this total production of ingots. The annual saving would thus be at least two million tons of coal—certainly an ample inducement for widespread adoption of this form of improvement.

Recent activity in this direction at several steel plants is seen to be fully justified when it is recalled that 45 per cent. of the total heat delivered to the open-hearth as fuel gas and combustible elements of the charge is wasted to the stack, and that one-half or two-thirds of this loss may be recovered by boilers at 60 per cent. or greater return on the investment. The heat thus saved is in the form of steam, and it is customary to express this saving in terms of the coal required in a boiler-house for generating the same amount of steam.

While the use of boilers in such applications as soaking pits and heating furnaces of regenerative type has not received a proportionate share of attention, yet the waste gas conditions are, or may be made, as promising for the generation of steam as in open-hearths. Generally speaking, a suitable boiler on any type of regenerative furnace will prove a paying investment, provided precaution be taken to minimize the wasteful and unnecessary cooling of the gas through infiltration of air and dissipation of heat.

The object of this paper is to describe briefly some of the representative open-hearth boilers, and to point out such results and operating experiences as may be indicative of savings elsewhere and helpful in future installations.

Early Boilers.

Fifty or more years ago the waste gases on the way to the stacks from puddling and heating furnaces of various kinds were passed under crude boilers, consisting

of single drums or shells 5 feet in diameter and 40 or more feet long, without flues or tubes. Although giving indifferent results, this practice marked the beginning of a train of improvements which led to the adoption of highly developed water-tube boilers for the reverberatory type of furnace. With regenerative furnaces, however, but little progress was made, and this was due to the low cost of fuel and relatively great investment required for recovering the reduced quantity of heat from the low temperature gases. Moreover, the limitations of open-hearth practice demanded a treatment the difficulties of which seemed greatly out of proportion to the prior simple installations with reverberatory furnaces.

Of first consideration in the use of boilers with an open-hearth are the requirements that the draft necessary for operating the furnace be not impaired, that the boiler equipment be made to fit the limited space available and, withal, to have ample surface and gas passages to efficiently handle the gases.

Some Existing Boilers on Open-Hearth Furnaces.

The first installation of an open-hearth boiler was made in 1910 on a 65-ton furnace at the South Chicago works of the Illinois Steel Company. Preliminary tests and calculations indicated that at least 60,000 pounds of gas per hour at a temperature of 1,200 degrees F. was escaping up the stack, and from these conditions it was estimated that the probable gross available output would be 175 boiler horsepower. As little was known of the requirements for this new service, a second-hand Heine water-tube boiler of the usual horizontal type, having 1,900 square feet of effective heating surface, was installed. This was done with the expectation that even if it should not prove entirely satisfactory for the purpose, at least it would provide a convenient means of making a study of the peculiar conditions.

The installation was made essentially as shown by Fig. 1. The entire equipment, particularly as to auxil-

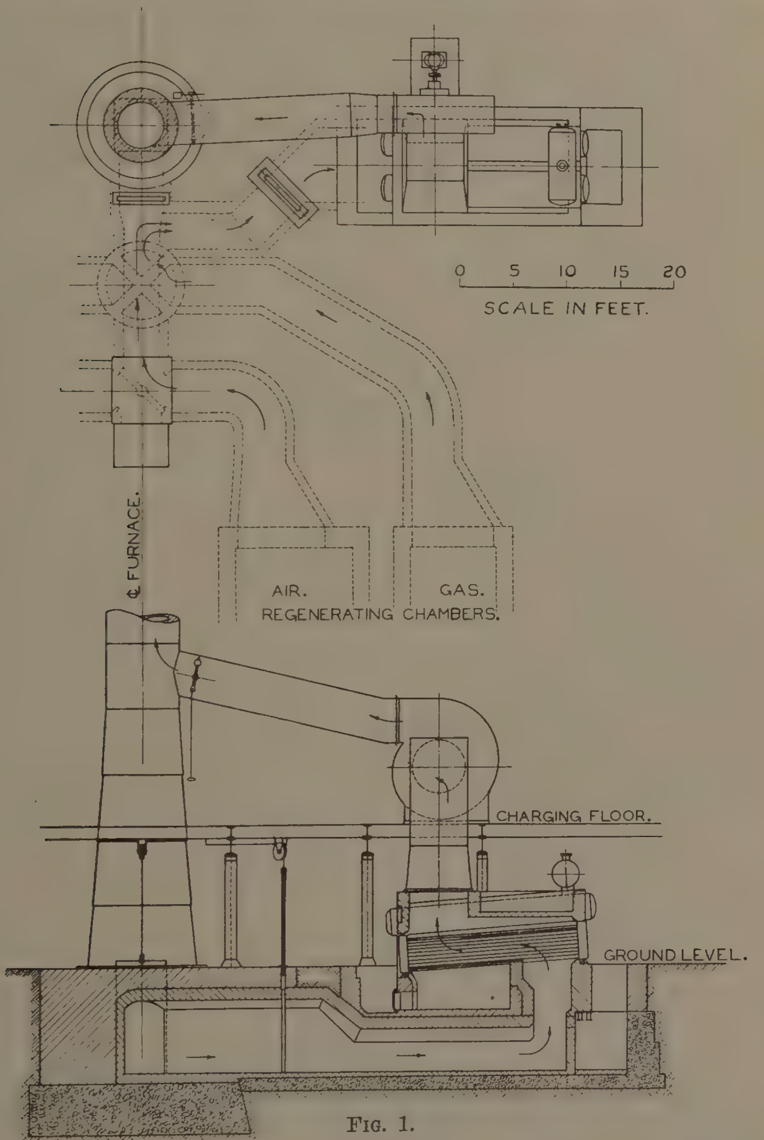


FIG. 1.

iaries and attachments, was made as simple as possible at the outset in order to facilitate the numerous changes and adjustments required in adapting it to the unknown conditions. The demand of the open-hearth furnaces for a draft of one and one-half inches, or more, in the stack

flue made it imperative that a fan be used between the boiler and stack to restore the loss of draft caused by the lower gas temperature and the friction through the boiler and connecting flues. The gases made a single pass over the heating surface, entering the bottom of the bank of one hundred and thirteen 3½-inch tubes near one end, and passing from the top of the bank at the other end.

After the boiler was put in service, in February, 1910, and desired adjustments made, a test of a month's duration showed a gross output of 190 boiler horsepower during furnace heats, with gas at an initial temperature of 1,150 degrees. Approximately 30 boiler horsepower was required for the engine-driven fan, the exhaust from which was not recovered.

Although these results were far from ideal, they were indicative of considerable economy in a comparatively unexplored region of open-hearth practice. Moreover, they demonstrated not only the practicability of application to open-hearth furnaces, without detracting from the tonnage or quality of steel, but indicated to what degree still greater steaming capacity could be realized by using larger boilers. In fact, it was evident that boilers with twice this amount of surface would be none too large for furnaces making 72-ton heats, consequently the following year two more boilers of larger size were installed in the same open-hearth plant, as shown on Fig. 2.

A special type of Stirling water-tube boiler was selected, known as "Class P-30," having 4,000 square feet of evaporating surface, but requiring relatively low head room, thereby permitting location entirely under the charging floor. They were provided with superheaters, special baffling, induced-draft fans, economizers, permanent soot-blowers, and other special features to favor not only the more extensive absorption of heat, but to provide facilities for more efficient operation and maintenance. Each boiler was divided into three passes, and was composed of 30 sections of tubes in width, each section having thirteen 3¼-inch tubes. At the rear of

the boiler setting, between the damper and fan, there was an economizer or feed-water heater made up of cast iron radiator sections, but it was soon removed, as it did not operate satisfactorily, due to excessive obstruction to the flow of gases and troublesome accumulation of dust on the irregular surface of the sections. The fans are of

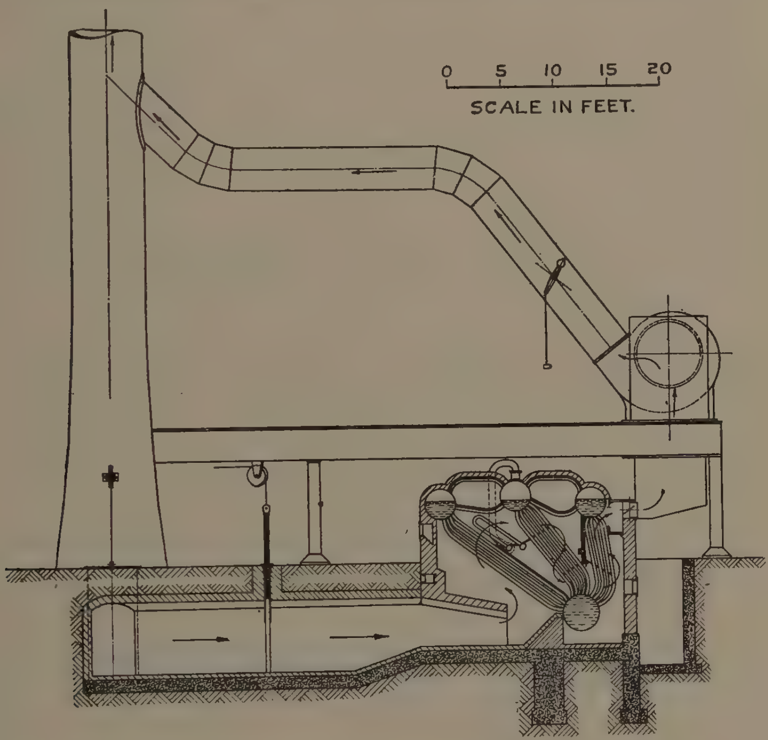


FIG. 2.

Sirocco type, with 72-inch wheels, especially constructed to suit the volume and temperature conditions, and driven by electric motors at a speed of 400 revolutions per minute, providing a total draft of four inches of water, nearly one-half of which is required to restore the amount of draft previously furnished to the open-hearth furnaces by the stack.

A series of 77 tests, each of the duration of an open-hearth heat, was made on these Stirling boilers with

varying temperatures and quantities of waste gases. In the following table are given the average results of ten tests with normal gas conditions:

Total duration of 10 tests	78.5 hours
Output of boiler and superheater	334.5 boiler horsepower
Feed-water temperature	60 degrees F.
Steam pressure	123.3 pounds gauge
Superheat	128.2 degrees F.
Inlet gas temperature	1,227.0 degrees F.
Outlet gas temperature	621.0 degrees F.
Weight of gases entering boiler	73,000 pounds per hour
Heat absorbed by boiler per hour	11,200,000 B.t.u.
Heat absorbed by boiler per ton ingots	1,575,000 B.t.u.
Draft loss through boiler	1.78 inches water

Rate of heat transfer, 5.08 B.t.u. per hour per square foot heating surface, per degree mean temperature difference between gas and steam.

It will be seen that an average of 335 boiler horsepower was obtained during heats when all the gas from the furnaces, or 73,000 pounds per hour, was passing through the boiler, and that the temperature was reduced from 1,227 degrees at the inlet to 621 degrees at the outlet.

Those two Stirling boilers, as well as the previously installed Heine boiler, have been in almost uninterrupted service since their installation, and recording instruments show an average output over long periods of time of about 280 boiler horsepower for each boiler, in addition to 25 horsepower due to the effect of heating the feed-water on the gas valves.

Following the investigations at South Chicago, 28 boilers were installed at another plant where the furnaces are of 85 tons rated capacity. As there was not sufficient room under the charging floor, Rust vertical boilers, each having 4,880 square feet of heating surface, were installed, as shown by Fig. 3.

This special type of boiler has six drums, three above and three below, two hundred and nine 4-inch vertical tubes, and the setting occupies a space 11 feet by 21 feet by 31 feet high. It has three passes for the gas and

liberal cross baffling to distribute the gases well over the heating surface. During the preliminary tests there was occasion to make several changes in the baffling in the effort to determine the most economical balance between heat absorption and draft loss, the final arrangement being as shown in the drawing. Superheaters having 346

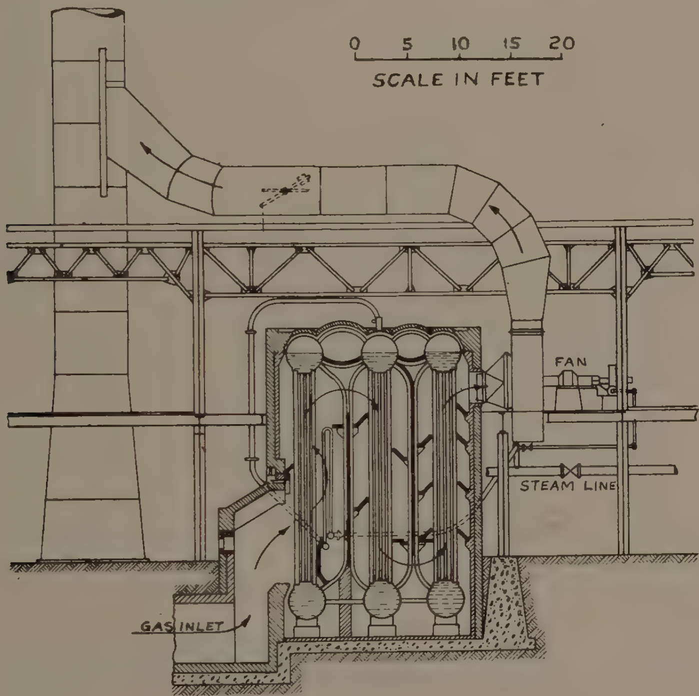


Fig. 3.

square feet of surface were located behind the bank of tubes in the first pass, where they were protected from the high temperature gases.

In this installation the fans, which have 90-inch diameter wheels, of special proportions to suit the high draft and temperature conditions, are driven by steam turbines, the exhaust of which is utilized in a central feed heating system, so that the net cost of fan operation is very low, being only seven boiler horsepower, or less than two per cent. of the gross output of the boiler. After

various changes the following continuous test was made, representing average conditions during heats:

Duration	152.2 hours
Output of boiler and superheater	393 boiler horsepower
Steam consumed by fan turbine	60 boiler horsepower
Steam returned to feed-water heaters	53 boiler horsepower
Net output of boiler	386 boiler horsepower
Steam pressure	126.1 pounds gauge
Temperature of superheated steam	530.8 degrees F.
Inlet gas temperature	1,155 degrees F.
Weight of gases entering boiler	83,434 pounds per hour
Heat absorbed by boiler per hour	13,200,000 B.t.u.
Heat absorbed by boiler per ton ingots	1,840,000 B.t.u.
Draft loss through boiler	2.48 inches water
Rate of heat transfer	6.92 B.t.u.

While these test results show that the average evaporation is 393 boiler horsepower during heats, 350 horsepower may be safely counted on for a year's average. The effect on open-hearth practice, as a rule, has been to materially reduce the time per heat.

Another installation of a single boiler is as shown on Fig. 4. This boiler deserves particular reference on account of the very high evaporation from a relatively small furnace of 30 tons rated capacity. It was found advantageous to locate the boilers entirely outside the open-hearth building, whereas in all installations elsewhere the boilers had been put under the open-hearth building between the stacks, where the construction cost was necessarily considerably higher, due to obstructions and alterations. So encouraging has been the performance of this boiler that steps are being taken to equip the remaining furnaces of the plant in a similar manner. The boiler is the B. & W. cross-drum type, having 2,605 square feet of heating surface in 162 four-inch tubes, divided into three vertical passes so that the gases pass transversely across the approximately horizontal tubes, a condition favorable to a high rate of heat transmission.

The following test of 120 hours' duration is representative of average conditions while making steel:

Output of boiler	200.2 boiler horsepower
Steam pressure	115.4 pounds gauge
Feed temperature	49.6 degrees F.
Inlet gas temperature	1,153.0 degrees F.
Outlet gas temperature	479.0 degrees F.
Weight of gases to boiler	41,470 pounds per hour
Heat absorbed by boiler per hour	6,700,000 B.t.u.
Heat absorbed by boiler per ton ingots	2,220,000 B.t.u.
Draft loss through boiler	1.92 inches water
Rate of heat transfer	6.86 B.t.u.

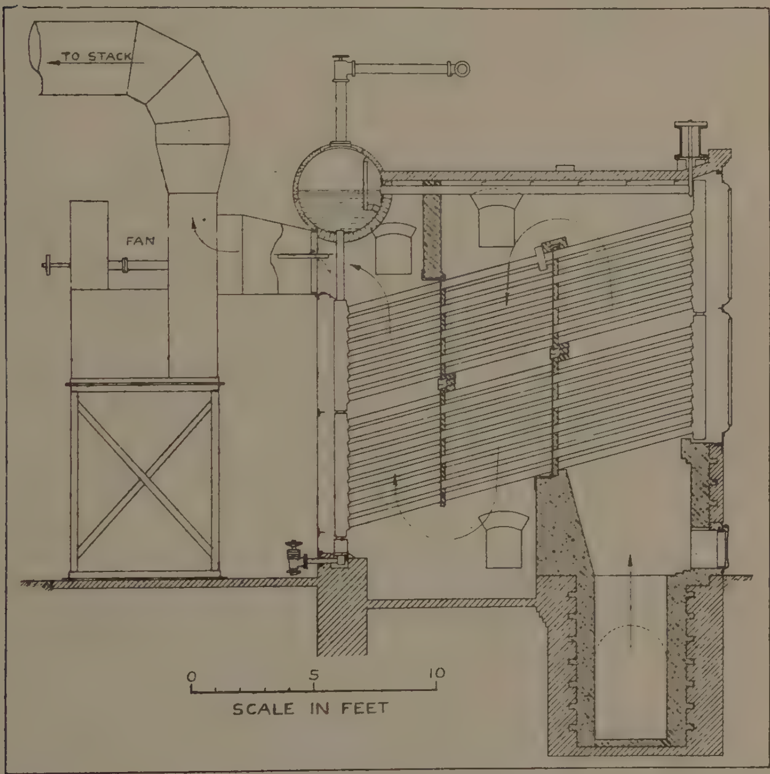


FIG. 4.

Although this test shows 200 boiler horsepower, a fair estimate of the average output over long periods is 170 to 175 horsepower without deducting the steam required for driving the fan engine, which in this instance is a considerable amount, since there is no means of recover-

ing the heat in the exhaust. In this case, as in others, there was an apparent reduction in the time required per heat. In addition to the boilers above described, several other installations have been made in various large plants.

With this above brief account of progress in some of the representative installations, it is opportune to draw some conclusions from the economical performance of present boilers, to outline the possibilities, discuss the operating difficulties, and direct attention to the avenues leading to further progress in design and operation.

Savings.

Experience with existing boilers has shown that the heat recovered is about 22 per cent of the heat in the coal charged to the producers, or about 1,600,000 to 2,200,000 B.t.u. per ton of ingots. In terms of coal containing about 11,000 B.t.u., this is equivalent to an average of 180 pounds per ton of ingots. It must be remembered, however, that this heat is in the form of steam which, if generated in coal-fired boilers at 60 to 70 per cent. efficiency, would require 250 to 300 pounds of coal. Other approximate statements of the saving are:

1,600 to 2,000 pounds steam per ton of ingots.
50 to 65 boiler horsepower hours per ton of ingots.
65 to 90 boiler horsepower hours per 1,000 pounds of coal charged in gas producers.

If the open-hearth fuel were natural gas, the boilers would generate about 85 per cent. as much steam as with coal, due to less weight of products of combustion. Pittsburg coal gives about 25 per cent. more waste gases per pound than Illinois coal, but on account of less coal consumed per ton of ingots only slightly more steam would be generated.

While the results of tests given in the above description of boiler installations show the output in terms of

"Boiler horsepower during heats," the average output over long periods, including average delays, Sundays, etc., appears to be from 80 to 85 per cent. of the test results.

In regard to the effect of boilers on the production of steel, it may be said that when the furnace is new the time required per heat does not appear to be affected to any marked extent, but as the furnace becomes old and the checkers fill up, the influence of the boilers becomes more evident, due to better and more uniform draft from the fans that draw the gases through the boilers.

Operating Difficulties.

Air leakage through the brick settings of water-tube boilers is the source of appreciable loss in efficiency, and the most attentive efforts to keeping the settings tight by pointing the brickwork and application of various paints and cements have not been entirely successful. Reports from all the existing installations speak emphatically on this point, and although in some instances excessive leakage has been temporarily overcome, nevertheless the liability of explosions in the flues, boilers and flues leading thereto demands constant attention, since the explosions loosen the brickwork of the boiler settings, not only increasing the air leakage, but incurring a high expense for repairs. These explosions are characteristic of open-hearth operation, being due to the escape of producer gas into the flues during the reversal of the gas valves, but may be somewhat reduced by close attention to manner of reversing.

The dust coming from the open-hearth furnaces and checker chambers is in an exceedingly fine and adherent condition and packs closely onto the boiler tubes, as well as on baffles and projections. There appears to be no means of preventing the dust entering the boilers, consequently the only remedy so far applied is frequent blowing with steam by portable and permanent soot-blowers. As a rule, blowing at intervals of six hours has been found sufficient, if the operation be thoroughly

performed, but after the dust has been allowed to remain it has a tendency to form a scale which is more difficult to dislodge than the freshly deposited dust. In addition to blowing the tube surface while the boilers are operating, the practice is to give them as thorough a sweeping as possible when out of service.

Cost of Installation.

The cost of installation is about 25 per cent. higher than for ordinary coal-fired boilers, in spite of the elimination of coal and ash handling equipment, stokers, etc., and this is due to the abnormal expense of construction work performed on isolated waste-heat units in cramped quarters, changes to buildings, underground flues and foundations, and to the necessity of applying large steam or motor driven fans. Some waste-heat boiler installations are being built during the construction of new open-hearth plants, and therefore should show a considerably reduced cost.

Weight of Waste Gas to Boiler.

The weight of gases from open-hearth and other furnaces is very difficult to determine. Accurate direct measurement is out of the question, due to lack of suitable conditions for use of meters. The weights mentioned above in the test results were calculated on the basis that total heat absorbed in the boilers required a certain amount of gas to be cooled between the initial and final temperatures. Radiation from the setting is small and not considered. This method is subject to serious error, due to uncertainty as to the specific heat of gases at these temperatures, and more particularly to the difficulty of obtaining representative temperature readings and gas analyses used in determining the amount of air leakage. Determining the weight of gas from the combustion of the fuel and elements in the charge would be a better method if the rate of fuel consumption during tests were accurately known, but this method also is affected by the

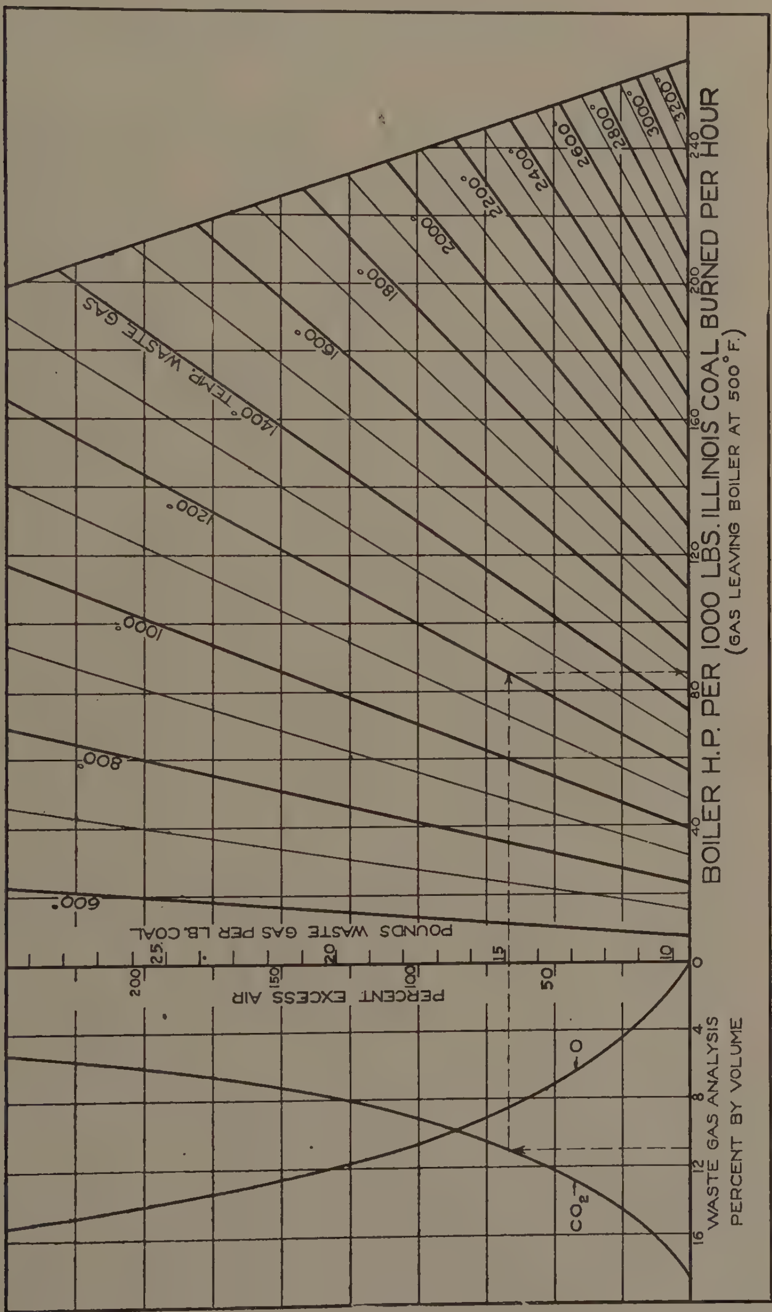

BOILER H.P. PER 1000 LBS. ILLINOIS COAL BURNED PER HOUR
(GAS LEAVING BOILER AT 500° F.)
1400° TEMP. WASTE GAS
POUNDS WASTE GAS PER LB. COAL
PERCENT EXCESS AIR
WASTE GAS ANALYSIS
PERCENT BY VOLUME
CO_2
O

FIG. 5.

accuracy of gas sampling. On account of this uncertainty, ample allowances should be made in the design of boilers, flues and fans. Air leakage has a serious effect on boiler output and fan work and should be eliminated by air-tight steel casings around the boiler settings when the water-tube boilers are used.

Fig. 5, giving the boiler horsepower available from waste gases, may be found useful in making quick determinations of amount of heat recoverable as steam.

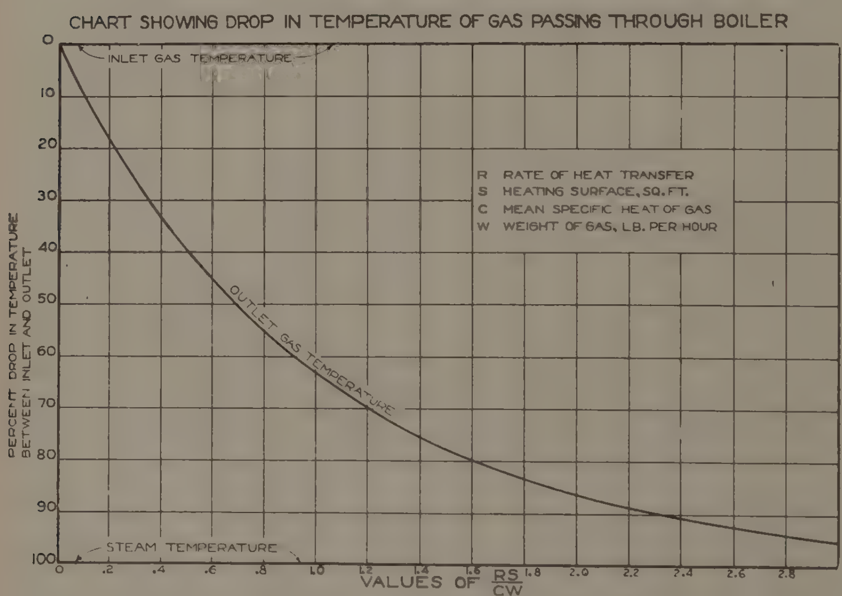


Fig. 6.

Although intended for Illinois lump coal the diagram may be used for Pittsburg run-of-mine by adding 25 per cent. to the results. If the open-hearth charge is about 65 per cent. pig iron, a further increase of 17 per cent. should be allowed for the additional gases formed by combustion of elements in the charge. Fig. 6 is reproduced herewith as it correlates many of the factors upon which depends the design of waste-heat boilers.

Heat Transmission and Boiler Design.

The subject of heat transmission, although indispensable for the proportioning of boilers to perform the maximum economy under given conditions, is hardly within the scope of this paper, but the following general statements are not out of place: The rate of heat transfer, expressed in terms of "B.t.u. per hour, per square foot of heating surface, per degree mean temperature difference between gas and steam," usually ranges between five and eight for boilers and somewhat less for superheaters and economizers. The fact that the size of boiler is inversely proportional to the rate of heat transfer is evidence of the importance of this subject. A considerable amount of empirical data applying to various commercial types of boilers has been collected, and in future installations it is hoped that steps will be taken to make further investigations. Theoretical formulæ and results of laboratory experiments are, as a rule, inapplicable in this work. The most essential factors conducive to high rates are clean surfaces and high gas velocity, the latter involving the direction of flow relative to the tubes. With water-tube boilers a good arrangement is to have the tubes in an approximately horizontal position with several vertical baffles, thereby enforcing the gases to impinge at high velocity against the tubes. However, in some cases it may be found more advisable that other considerations, such as the proportions of the available space, provisions for keeping the boiler clean, friction loss in the gas flow, etc., be given precedence in the design.

While the rate of heat transmission in fire tubes is not as great as in water tubes of the same diameter and at the same gas velocity, yet it is possible that the advantages to be expected from fire-tube boilers especially designed for waste-heat purposes may offset the loss in heat transfer. Among the points in favor of such boilers are simplicity, absence of air leakage, resistance to gas explosions and relatively low cost for the same capacity.

In order to maintain the maximum economy with any type of boiler it is absolutely essential that the heating surface be kept clean in the full sense of the word. This is one of the most troublesome operating problems, and, while frequent use of permanent and hand soot-blowers is fairly efficient, the design of the boiler should be such as to prevent as far as possible the lodgment of dust and to facilitate rapid and easy cleaning while in as well as out of operation. With the advent of pulverized coal for various heating operations, the subject of maintaining a clean boiler becomes of even greater importance, due to the large quantity of ash.

In deciding on the type and location of the boiler it is desirable that the parts requiring frequent attention of the operator be above the charging floor, or where working conditions, such as ventilation, light and cleanliness, are better than under the charging floor. In many cases this desideratum eliminates all but the vertical type of boiler.

Possibilities of Further Savings.

While the savings herein pointed out represent a marked economy in open-hearth practice, still there is opportunity for improvement in new installations by means of larger boilers and more attention to reducing the heat losses resulting from air leakage and radiation in the regenerative chambers, valves and flues.

In the table some figures are given showing what proportion of the heat delivered to the furnace may be utilized in a waste-heat boiler. This is based on reducing the gas temperature from 1,200 degrees at the inlet to 500 degrees at the outlet, and is the minimum performance that should be striven for. Although present boilers are showing very creditable savings, the outlet temperatures, neglecting the cooling effect of air leakage, are 600 degrees or higher, but the majority of these boilers are so situated that larger boilers could not be readily used.

Wherever space permits, the aim should be to reduce

HEAT BALANCE OF OPEN-HEARTH FURNACE.

	B.t.u. per hour.	B.t.u. per ton ingots.	Per cent. of heat in coal.	Per cent. of heat in fuel gas.	Per cent. of heat to furnace.
Coal to gas producers	52,500,000	7,000,000	100.0		
Producer loss......	8,620,000	1,150,000	16.4		
Heat delivered to furnace.					
Gas from producers	43,890,000	5,850,000	83.6	100.0	
Combustion of C, Si and Mn in charge	9,370,000	1,250,000	17.8	21.4	
Sensible heat of hot metal	3,450,000	460,000	6.6	7.9	
Total heat to furnace except regenerated gas and air..........	56,710,000	7,560,000	108.0	129.3	100.0
Distribution of heat.					
Consumed in furnace and losses.......	31,450,000	4,192,000	59.9	71.8	55.5
Utilized in boiler..	15,510,000	2,068,000	29.5	35.3	27.3
Wasted to stack at 500° F..........	9,750,000	1,300,000	18.6	22.2	17.2
Total.......	56,710,000	7,560,000	108.0	129.3	100.0

These results are based on the following empirical data:

Size of heats, 75 tons.
Time per heat, 10 hours.
Hot metal in charge, 64 per cent.
Ratio, product to charge, 88 per cent.
Fuel consumption, 4,875 pounds per hour, or 650 pounds per ton.
Heat value of coal, 10,700 B.t.u. per pound.
Weight waste gases at boiler, 81,400 pounds per hour.
CO_2 in waste gases at boiler, 12 per cent.
Temperature waste gases at boiler inlet, 1,200 degrees F.
Temperature waste gases to stack, 500 degrees F.
Performance of boiler under above conditions, 460 boiler horsepower.

the temperature even as low as 400 degrees, where would be realized the maximum net saving per ton of steel, although not necessarily the maximum return on the investment. The size of boiler required for reducing the temperature from 1,200 to 400 degrees is two and one-half times the size for reducing to 600 degrees, yet at not a proportionately greater investment.

The initial gas temperature also demands further attention. Whereas now the average is not over 1,150 degrees for open-hearth furnaces in general, there is no question that it can be increased to at least 1,400 degrees. One source of loss is the practice of water-cooling the

gas and air valves. Although not detrimental in ordinary open-hearth practice, this results in a considerable loss when the recovery of waste heat is attempted. The heat thus lost may be recovered either by utilizing the cooling water for feeding the boiler or by substitution of brick-lined gas valves, thereby giving the waste gases a higher temperature on entering the boiler.

The recovery of heat in the waste gases from regenerative soaking pits and heating furnaces presents additional encouraging possibilities, but as a primary consideration, means must be adopted for greatly reducing the heat losses and excessive air leakage which appears to be characteristic of these types of furnaces. Even if the gas temperature be considerably lower than in open-hearth practice, boilers will be found a paying investment; and heat recovery, by this means, does not cease to be economical until the temperature, at the boiler inlet, is as low as 700 degrees.

President Gary: We will now have a discussion of Mr. Bacon's paper under the five minute rule by Mr. Roy A. Lewis, Assistant General Superintendent of Bethlehem Steel Company, and by Mr. David S. Jacobus, Advisory Engineer of the Babcock and Wilcox Company, after which the paper will be open for further discussion under the five minute rule.

After the general discussion of Mr. Bacon's paper shall have been completed, Mr. Daniel M. Buck, Metallurgical Engineer of the American Sheet and Tin Plate Company, will read a paper on Recent Progress in Corrosion Resistance. To save time I shall ask each gentleman to come forward in their sequence without further introduction.

WASTE-HEAT BOILERS FOR OPEN-HEARTH FURNACES

Discussion by Roy A. Lewis
Assistant General Superintendent, Bethlehem Steel Company, South Bethlehem, Pa.

Mr. Bacon's paper brings to general attention the saving that can be effected by the use of waste-heat boilers in connection with open-hearth furnaces. He was the first to point out the advantages of this scheme, and provided the first practical data from which installations could be planned. The Bethlehem Steel Company recognized two years ago the opportunity this offered, and placed an order for waste-heat boilers of the Babcock & Wilcox Cross Drum type.

The boilers are set on the charging floor, the structural steel supports of the floor being re-enforced to carry the boiler and the brick setting. A vertical flue leads upward from the gas passages directly into the boiler setting. The induced draught fan also is placed on the charging floor and is driven by a motor. The arrangement is shown on Figure 1. This location has proven to be a very desirable one. The arrangement of the fan, however, could be improved by a more direct breeching connection between the fan and boiler. The first boiler in commission was tested continuously day and night during a period of some four weeks, and, all told, complete test data representing 28 heats was obtained. Later a similar set of tests was run on one of the other boilers. The results of these tests combined into runs during which all data was taken continuously is given in table 2.

Air Leakage.

Particular attention was paid to air leakage into the setting. Consistent samples of the gas for analysis entering the setting could be obtained, due to the comparatively

long vertical flue leading to the boiler, and also the gas leaving the boiler could be determined fairly accurately. The weight of gas entering the boiler was calculated by the method described in Mr. Bacon's paper, from the heat absorbed by the boiler, and a corection was made for leakage. The weight of gas was also determined from the gas analysis, and the total amount of carbon in the gases. The total amount of carbon was obtained from the weight of coal charged to the producers, and the weight of the limestone and hot metal in the furnace charge. These weights were taken continuously on all tests of the boiler connected with No. 29 furnace. The check between the weights obtained in these two entirely dissimilar ways was very close. It would appear that the air leakage varies between 10 and 30 per cent. When all openings around doors, door frames, buckstays, smoke connections, etc., are plugged with asbestos, and the setting painted over with tar paint, the leakage could be kept down to 10 per cent. No precautions being taken to stop any leaks, the leakage would be around 30 per cent. Very little of the air leakage seems to come through the brickwork proper, as painting the setting reduced the leakage little, if any. The air comes in principally through the joints between brickwork and metal. Covering the face of the walls, therefore, with a sheet-metal casing would not necessarily diminish the leakage. Part of the leakage measured came in at the rear of the boiler, after the gases had passed over the heating surfaces, and, therefore, did not affect the steaming capacity, but the analysis taken throughout the setting would indicate that there was a general leakage from the beginning to the end of the path of the gases.

Determining the weight of the gas passing through a fan is usually a very difficult matter, but, in this instance, the weights were apparently fairly accurate. The fan was driven by an electric motor, and the power used could be measured. It was of the steel plate type, having a wheel 6 feet 6 inches in diameter, in a casing ordinarily

used with a 6-foot wheel. It would appear that the efficiency was between 55 and 60 per cent., the effective work being taken as the volume of the gas times the difference in pressure between the inlet and outlet of the fan, when both are expressed in the proper units and no allowance made for electrical losses. This was a better efficiency than was anticipated, but I believe is not as high as would be obtained from a still larger fan, driven at a slower speed. The saving effected in operating the fan is, of course, just as much value as an increased heat absorption in the boiler.

Keeping the heating surface of these waste-heat boilers free from dust is very important, as Mr. Bacon has pointed out. In the tests on the boiler on No. 29 furnace, the dusting was done by hand. An ordinary steam lance was used, and the boiler was gone over about once every eight hours. In the test on the boiler connected with No. 26 furnace, permanent dusting pipes were

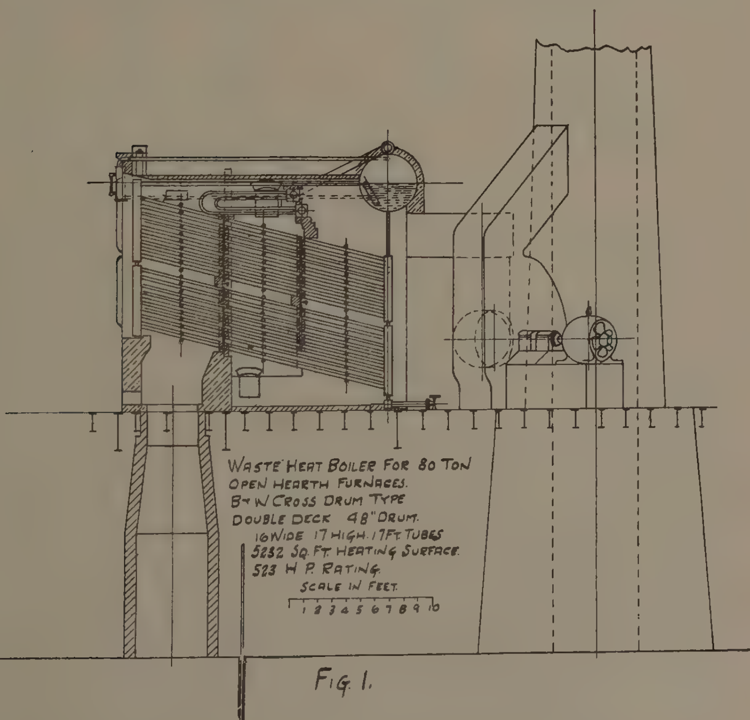


FIG. 1.

installed in the setting, but in this particular case the results were not satisfactory.

SUMMARY OF THE RESULTS OF THE TEST OF WASTE-HEAT BOILERS CONNECTED WITH OPEN-HEARTH FURNACES AT THE SAUCON PLANT OF THE BETHLEHEM STEEL COMPANY.

Furnace number	29	29	29	26	26
Duration of test, hrs	121:10	50:00	159:00	143:00	69:15
Number of heats taken during test	11	4	13	14	6
Average weight of ingots per heat, tons	78.3	81.4	83.6	83.9	80.3
Output of boiler and superheater, BHP	392.6	367.4	425.8	332.2	343.1
Steam pressure, lbs. per sq. in	145	144	139	145	147
Superheat, degrees F	106	106	121	125	107
Inlet gas temperature, degrees F	1,328	1,253	1,362	1,180	1,192
Outlet gas temperature, degrees F	489	482	493	534	507
Weight of gases entering boiler, lbs. per hr	70,092	68,954	75,271	75,320	75,383
Draught loss through boiler, in. of water	1.73	1.88	1.74	1.74	1.98
Effective draught by fan	3.47	3.57	2.80	2.99	3.10
Electrical H. P. required to drive fan	38.1	39.6	32.1	29.6	35.2
Boiler H. P. charged to fan	28.9	30.0	24.3	22.4	26.7
Net output of boiler and superheater, H. P.	363.7	337.4	401.5	309.8	316.4

NOTE: Boiler, B. & W. Cross Drum; 16 sections wide; 17 tubes high; 5,232 sq. ft. of heating surface.

RESULTS OBTAINED.

The credit given to the open-hearth plant for the steam furnished is such that if the plant is kept in operation continuously, the cost of the installation would be paid for in less than two years' time. Where the gas temperatures are higher, the investment is, of course, better.

The operation of the furnaces on which waste-heat boilers have been used has been very carefully watched. The control of the draught given by the fan, which is driven by a variable-speed motor, has been beneficial, and the production has been somewhat increased, especially as the furnaces become old and congested. (Applause.)

WASTE-HEAT BOILERS

Discussion by David S. Jacobus
Advisory Engineer, The Babcock and Wilcox Company,
New York City.

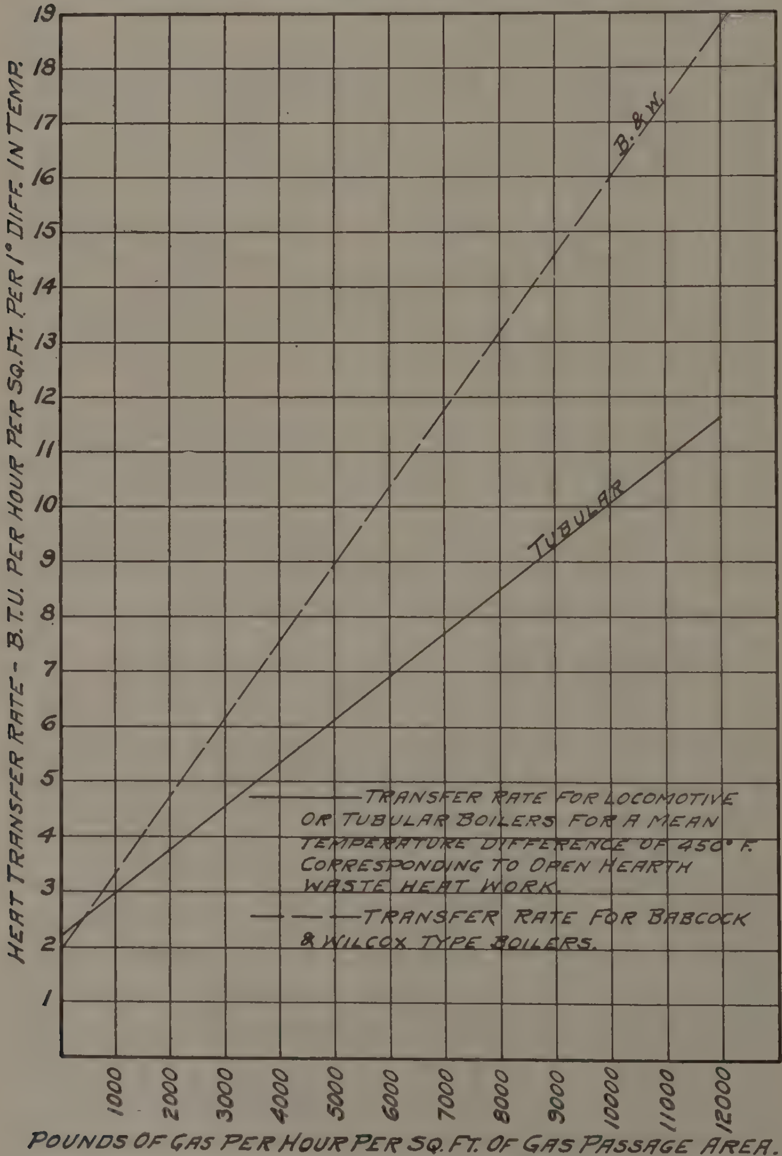
Mr. Bacon and his associates at South Chicago deserve great credit in being the pioneers in applying waste-heat boilers to open-hearth furnaces. Utilizing waste heat in a boiler is, of course, an old idea, and it might seem a simple step in such a case to attach a waste-heat boiler, but the man who does a thing of the sort first and runs the risk of failing and being told, "I told you so," deserves ever so much credit, especially where any interference with the operating conditions would count as much against the plant as it would in an open-hearth furnace.

It was my privilege to be associated with Mr. Bacon in the early stages of his work. This resulted in the Babcock & Wilcox Company making a careful study with a view of determining the best way of applying boilers to the particular class of service. And right here I might say that the investigation resulted in a radical change in our waste-heat practice.

The first boilers we put in at South Chicago were Stirling boilers with special baffles, this type of boiler being used to meet space limitations. Before installing these boilers we made figures galore, and predicted what capacity would be developed, and our investigations made us feel safe in using heat transfer rates higher than we felt warranted in using in our old waste-heat practice. The capacity of the boilers came out just about as we figured it, which was a source of much satisfaction. Mr. Bacon has also mentioned another source of satisfaction, which was that the capacity of the open-hearth furnaces was increased, so that instead of the boilers interfering with the operation of the furnaces there was a gain, especially when the checkerwork became dirty.

Mr. Bacon was also in touch with the next installation where Rust boilers, which have vertical tubes, were used. The Rust boilers were carefully tested, and, as shown in the paper, were found to give good results.

We finally installed Babcock & Wilcox boilers, in which



the tubes are more nearly horizontal than in the Stirling or Rust boilers, and found, as pointed out in the paper, that we obtained a greater capacity per square foot of heating surface with a lesser draft resistance, which bears out the conclusion that this type of boiler is the best form of water-tube boiler for the purpose. The latter boiler can be made any width and any height, with the result that one can obtain any desired length of travel of the gases and can make the velocity of the gas such as to best meet the conditions involved.

We have built many waste-heat Babcock & Wilcox boilers in accordance with our new ideas, some of which are used for other work than for open-hearth furnaces. In one case the boilers are run slightly below 200 per cent. of their rating, that is, with an evaporation of about 6 pounds per hour per square foot of heating surface, and each boiler is generating about 2,000 horsepower with the waste gases leaving the boilers at a temperature of less than 450 degrees F. The art has developed to a state where the utilization of waste heat by our newer methods is a large movement, and the beginning of this movement was in South Chicago, where the first experiments were made.

A chart is added herewith, at Mr. Bacon's request, which gives the approximate rate of heat transfer of fire-tube and water-tube boilers. This is shown in Fig. 1, in which the ordinates are the heat transfer rates and the abscissa the weight of gas per square foot of gas passage area flowing through the boilers per hour. The law is not shown completely in Fig. 1 as the rate of heat transfer will vary with the mean temperature difference between the gas and the boiler. The conditions selected are such as most nearly meet ordinary open-hearth furnace waste-heat practice.

The Babcock & Wilcox Company has recently completed an extended series of elaborate tests to determine the rate of heat transfer, the results of which will shortly be published. (Applause.)

RECENT PROGRESS IN CORROSION RESISTANCE

DANIEL M. BUCK

Metallurgical Engineer, American Sheet and Tin Plate Company,
Pittsburgh, Pa.

As materials of construction, steel and iron stand preeminent today. This enviable position is a natural result obtaining from the prevalence in nature of the raw materials necessary to their manufacture, to the comparative ease and low cost of conversion, to the valuable properties inherent in the finished products, and to the fact that the physical properties may be changed almost at will to meet the largely diversified requirements of the consumers.

Hardness, strength and elasticity may be varied by the introduction of carbon. Machining operations may be greatly benefited by the introduction of sulphur in reasonable amounts; by silicon additions, electric properties are improved; and the ductility is increased by the introduction of copper. By judicious alloying with nickel, chromium, tungsten, molybdenum, manganese, etc., are obtained the wonderful projectile-resisting armor plate, the valuable high-speed steels which retain their temper under severe conditions, and the extremely hard manganese steel which is so useful in abrasion resistance. By varying the forming and heat treatment operations, the properties may be further modified and governed, and this wonderful metal "steel" made to serve man's ends.

But there is one property which steel and iron do not possess—that of stability when exposed to the action of air and water.

In an effort to combat this tendency of iron to return

to its original (oxide) form, much serious thought has been given by metallurgists and students of corrosion problems. We believe that all are agreed that the ideal condition is to so protect the surface of the ferrous materials as to permanently exclude the corrosive elements. To attain this Utopian condition, protective coatings of various types are used.

Protective Coatings.

1—Oxidizing the materials, thus covering the surface with a more or less uniform and adherent coating of electro-negative oxide of iron, which is an efficient protector only so long as it remains intact. Any coating electro-negative to the base material, if broken or removed at any point, becomes an accelerator of corrosion at that point when exposed to corrosive influences. This is due to electrolysis between the electro-negative coating and the electro-positive steel or iron. The reverse is true when considering a coating electro-positive to iron, in which case the coating will protect to a considerable extent at its own expense, even though slightly fractured or scratched.

There are many processes by which these oxide coatings may be produced, but lack of time forbids a detailed discussion at this time. In the writer's opinion the remarkable life of some of the ancient specimens of iron has been due to such an enamel-like film of oxide, necessarily produced by the crude manufacturing processes of our forebears.

2—Coating with other metals, such as zinc, tin, lead, copper, nickel, aluminum, etc. Of these zinc, and to a lesser degree aluminum, are probably the most important, since they are the only ones which are electro-positive to iron, thus affording, in addition to their excluding power, an electro-chemical protection in the manner mentioned above. This property under most conditions, in our opinion, outweighs the somewhat lower solution pressures of the metals which are electro-negative to iron.

3—Covering the surfaces with a paint-film consisting of pigments intimately mixed with some vehicle, usually linseed or other suitable oil.

Careful attention should be given to the designing of a proper paint, since it is believed that some pigments are actual accelerators of corrosion, while others range themselves in the inhibitive class.

4—Additional resistance to corrosion is obtained by certain mechanical treatments during the rolling operations. The most important of these is probably the Spellerizing operation, which, when applied to pipe and tubing, has given satisfactory results.

Inasmuch as no absolutely rust-proof steel or iron has ever been devised, the writer recommends that, wherever possible, construction materials which are to be exposed to corrosive influences be protected by a metallic coating, a suitable paint, or both. There are, however, conditions when such a protection is either not possible or not desirable, and it is also true that film coatings, on account of their liability to be removed by accident and abrasion, and by the action of the weather, are only a more or less temporary protection. Consequently, much thought has been given to the possibility of producing a steel or iron which in itself possesses corrosion-resisting properties.

Differences of Opinion.

After years of research, investigation and practical experience, there is unfortunately at the present time not a complete unanimity of opinion on this subject. This difference of opinion is the result of several causes, some of which are avoidable:

An undue adherence to theory without practical demonstration of the value of the theory;

An undue and reprehensible adherence to a particular class of product with which the investigator may be interested financially or otherwise;

Placing too much confidence in accelerated tests;

Losing sight of the fact that under the best practices heats below the average are manufactured in all classes of products, and the consequent drawing of conclusions from comparing a good heat of one type with a poor heat of another type;

Drawing *general* conclusion from results obtained under *peculiar* conditions, which may or may not be in any way representative.

The adherents of the different schools are divided into four main classes as follows:

First—Those who believe in genuine iron, the product of the puddling furnace;

Second—Those who believe in normal mild steels, the product of the open hearth and Bessemer furnaces;

Third—Those who believe in so-called pure irons, the product of the open hearth furnace, in which the carbon and manganese are reduced to a minimum, and to which copper may or may not be added;

Fourth—Those who believe in normal open hearth and Bessemer steels with which has been alloyed a small amount of pure copper. Attempts have also been made to use nickel as the alloying element.

Copper Alloy Steels.

The writer, after many years of careful study and investigation, is one of the firm believers in the fourth type mentioned—copper alloy steels. Our investigations have dealt principally with the exposure and observation of full-sized sheets, unprotected in any way, under service conditions. Many different heats have been used in our work, thus eliminating the chance of accidental results. The majority of our tests have been made under atmospheric influences. We realize that it is impracticable to make tests under all of the many varying conditions, and believe that atmospheric corrosion is the most important, especially when considering structural material in general and sheets and plates in particular.

We will briefly review some of our earlier work on

this subject, a part of which has already been published.

About five years ago, in testing the corrosion resistance properties of sheets made from electric furnace steel, it was noticed that one heat of steel which contained about .07 per cent. copper was markedly superior to the others in its resistance to corrosion. Some further work indicated that the results obtained were not accidental, and that the copper was probably the controlling factor. To remove the last element of doubt, several heats of both Bessemer and open hearth steel were used and copper added in varying amounts to some of the ingots as they were poured, while to other ingots of the same heat no additions were made. Careful surveys of both the bars and sheets rolled from these ingots proved that the diffusion of the copper under these conditions was practically perfect. These ingots were rolled into 16-gauge and 27-gauge sheets and exposed to the atmosphere in the Pennsylvania coke regions, at Atlantic City, N. J., and along the Allegheny River above Kittanning, Pa., thus obtaining widely varying conditions of atmosphere.

Tests and Their Results.

A partial report of the results of these tests was made by the writer in a paper before the American Chemical Society, in March, 1913. For the present purpose we will briefly refer to a photograph (Fig. 1) of one of the first tests made in the coke region. This shows 27-gauge sheets after about seven months' exposure. As will be seen, certain of the panels, those to which copper was not added, had started to fail.

Fig. 2 is a photograph of the same roof after about one year's exposure. The steel without copper had entirely corroded away, while the copper-bearing sheets from the same heats were in excellent condition.

Table 1 gives the analyses of the various grades of steels in the test and their relative values in corrosion resistance, as obtained by weight tests of small pieces cut from the large sheets shown in the photographs.

TABLE 1, SHOWING RELATIVE LOSSES ON 2×4 IN. TEST PIECES.

Exposed in coke regions November 21, 1911, and taken down August 14, 1912.

Each result is the average of six pieces.

(Mill scale was removed from all samples before exposure, and all were cleaned with ammonium citrate solution before final weight.)

Grade	Panel	Ga.	Analysis					Position	Relative Losses, 100 Equals Greatest Corrosion
			Carb.	Mang.	Sul.	Phos.	Copper		
Bessemer	8	27	.05	.44	.082	.101	.23	1	39.09
Bessemer	9	27	.05	.44	.075	.099	.34	2	39.61
Bessemer	9	16	.07	.46	.069	.095	.33	3	41.57
Open Hearth	5	27	.10	.46	.035	.043	.17	4	42.09
Open Hearth	6	27	.07	.47	.038	.043	.25	5	42.22
Open Hearth	3	27	.06	.33	.035	.018	.25	6	43.27
Open Hearth	2	27	.06	.35	.036	.018	.16	7	43.92
Bessemer	8	16	.08	.45	.070	.094	.21	8	44.05
Open Hearth	6	16	.14	.46	.038	.043	.27	9	46.67
Open Hearth	5	16	.13	.44	.035	.042	.18	10	46.67
Open Hearth	3	16	.10	.35	.033	.019	.23	11	47.32
Open Hearth	2	16	.10	.34	.035	.020	.16	12	48.36
Low Carbon and Low Manganese Material	10	27	.02	.03	.036	.003	.07	13	50.19
Low Carbon and Low Manganese Material	10	16	.03	.03	.034	.003	.06	14	53.20
Open Hearth	4	16	.13	.45	.035	.042	.00	15	74.64
Open Hearth	4	27	.09	.47	.037	.043	.00	16	78.16
Bessemer	7	16	.08	.46	.070	.098	.00	17	91.64
Bessemer	7	27	.05	.45	.076	.100	.00	18	96.86
Open Hearth	1	16	.10	.34	.034	.019	.00	19	98.82
Open Hearth	1	27	.06	.35	.033	.018	.00	20	100.00

Fig. 3 is a photograph of the 16-gauge sheets taken in February, 1915, after a little more than three years' exposure. Two of the plain steels have absolutely failed, while the third, Panel 4, which is rephosphorized basic open hearth, is in poor condition. The copper-bearing panels are, after three years' exposure, nearly as good as when first installed, and, so far as we are able to determine by observation, have not changed in any way in the past two years. Similar results were obtained at the other two test stations.

On March 4, 1913, a second series of sheets was exposed in the Pennsylvania coke regions, and Figs. 4 and 5 are photographs taken after 10 and 16 months, respectively. The remarkable inhibitive power of the copper content is strikingly shown in the photographs.

Panels D, E, V, Z and ZZ are copper-bearing steels.

FIG. 1.

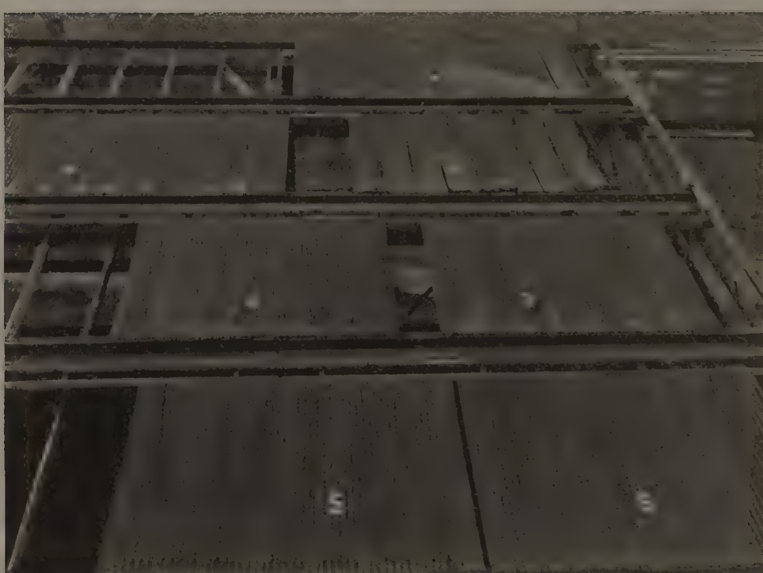


FIG. 2.

FIG. 3.

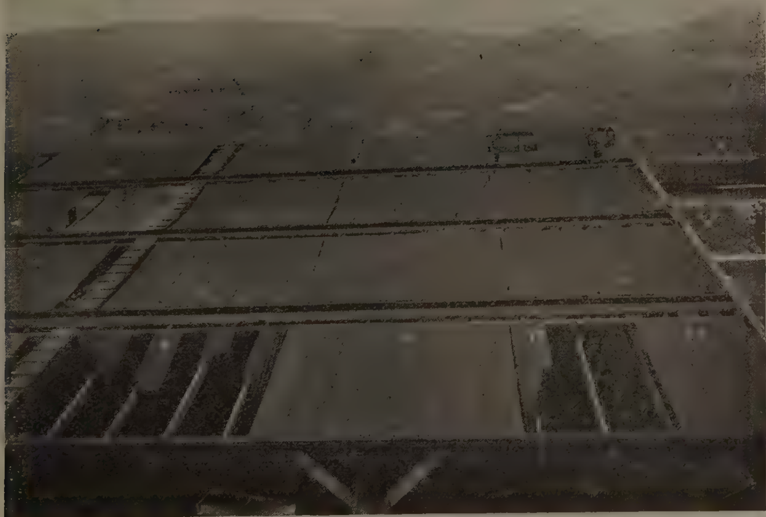


FIG. 4.

Panels Y and YY are plain open hearth steels, without copper additions.

Panel F is reworked muck iron.

Panel I is genuine charcoal iron.

Table 2 gives the analyses of the above-mentioned panels, and of the other grades H, O, W and J. It will be noted that the copper alloy steels have outlasted even the genuine iron sheets.

The writer, collaborating with Mr. J. O. Handy, is at present conducting a corrosion test in two different localities. In these tests are included 700 full-sized sheets of 44 different characters of steel. This test should be completed in approximately six months from the present date and will no doubt give us some additional valuable information which will be made the basis of a subsequent paper. In this series we have included copper additions in amounts from approximately .04 to 2 per cent., and we have also made additions of sulphur, phosphorus, aluminum, silicon, mill scale and steel turnings. Although the sheets have been exposed only about ten months, and we have not yet completed our observations, we are already able to draw some interesting conclusions.

Figs. 6, 7 and 8 show three sections of one of these test racks after about nine months' exposure. Panels 15 and 16 are from the same heat of Bessemer steel, which carried .14 per cent. residual sulphur. Panel 15 has .25 per cent. copper, and Panel 16 .008 per cent. copper. Panels 17 and 18 are from another heat of Bessemer steel with .052 per cent. residual sulphur; Panel 17 being copper-bearing, Panel 18 .004 per cent. copper. It will be noticed that, considering the plain steels, Panel 16 (high sulphur) has corroded much faster than has Panel 18 (normal sulphur); while it is interesting to note that there is no difference discernible between Panels 15 and 17, both copper-bearing. Up to the present time the sheets with high copper content, up to 2 per cent., are not showing any better corrosion resistance than those containing only .25 per cent.; and, indeed, from present

TABLE 2, CORROSION TESTS ON 2×4 IN., 27-GAUGE TEST PIECES.

Exposed to weather for 8 months at Scottdale, Pa.

The results are the average of 8 tests of each grade.

(Mill scale was removed from all samples before exposure, and all were cleaned with ammonium citrate solution before final weight.)

	Grade	Analysis						Loss in Oz. Per Sq. Ft.	Rank	Relative Losses, 100 Equals Greatest Corrosion	Condition of Test Pieces After Exposure
		Carb.	Mang.	Sul.	Phos.	Sil.	Copper				
V	Bessemer	.04	.39	.078	.114	....	.31	3.15	1	42.63	No Holes
E	Open Hearth...........	.04	.30	.043	.065	....	.31	3.24	2	43.84	No Holes
ZZ	Open Hearth Unannealed.	.11	.45	.049	.099	.011	.25	3.32	3	44.93	No Holes
Z	Open Hearth Annealed. Same heat as ZZ......	.04	.43	.049	.099	.011	.25	3.33	4	45.06	No Holes
H	....	.042	.16	.024	.003	....	.21	3.39	5	45.87	No Holes
D	Open Hearth...........	.06	.50	.037	.016	....	.26	3.50	6	47.36	No Holes
C	Open Hearth...........	.06	.33	.035	.018	....	.25	3.51	7	47.50	No Holes
O	....	.027	.07	.033	.007	....	.09	3.69	8	49.93	No Holes
W	....	.049	.05	.043	.005	....	.10	3.88	9	52.50	Holes in two Pieces
I	Charcoal Iron...........	.03	.06	.013	.052	.039	.07	4.04	10	54.67	Holes in three Pieces
J	....	.022	.03	.031	.006	....	.034	4.12	11	55.75	Holes in one Piece
F	Reworked Muck Bar......	.04	.07	.023	.134	.162	Trace	4.66	12	63.06	Few Holes in all
YY	Open Hearth Unannealed.	.11	.45	.048	.096	.007	Trace	5.11	13	69.15	Many Holes in all
Y	Open Hearth Annealed. Same heats as Z and ZZ	.04	.45	.046	.099	.006	Trace	7.39	14	100.00	Only lace work left

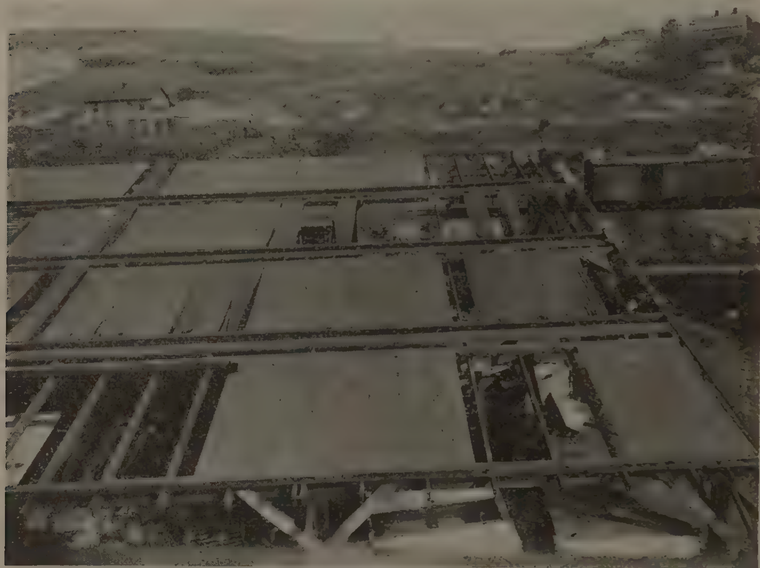


FIG. 5.

FIG. 6.

indications the beneficial influence of the copper content is quite marked down to at least as low as .04 per cent. copper. Panel 8 has silicon added and is failing badly, as are also Panel 9 with aluminum addition, and Panel 10 with a sulphur addition. As was expected, the addition of steel turnings to the molten steel has been of no benefit.

From our work to date we are prepared to draw the following conclusions as to the influence of the varying metalloids in steel sheets when exposed to the atmosphere:

Carbon.

Although there has been no attempt made to determine directly the carbon influence, it seems that in the low ranges present (.02 to .14 per cent.) in mild open hearth and Bessemer steel, carbon has little influence. This is indicated by a study of the tables which we have given with this paper.

Manganese.

While the writer is aware that some metallurgists advance the theory that a content of manganese is detrimental to steel in its corrosion resistance, we neither agree with the theories advanced nor have we observed the slightest evidence or proof that such claims are justified. Much the greater part of the manganese present in steel exists alloyed with the iron, in which form we would not expect it to influence corrosion as far as the electrolytic theory is concerned, since two materials differing chemically or mechanically are required to start electrolysis, and these conditions are not obtained by simple alloying. Some of the manganese unites with sulphur, forming manganese sulphide, which exists in isolated patches and which is at best only a feeble conductor of electricity, and as such should stimulate corrosion to only a slight extent, if at all. It is possible that these patches of manganese sulphide, when they occur at the surface of the steel, or as they become exposed by

Fig. 7.

Fig. 8.

the wasting of the steel, become oxidized to sulphates, in which form the efficiency of the moisture as an electrolyte would be increased. This action, however, is due to the presence of sulphur and not to the presence of manganese. Sulphur in steel must exist in combination, and if there is not sufficient manganese present, it will unite with the iron, forming iron sulphide, in which form it will be at least as harmful as in the form of manganese sulphide. Tests made by Burgess and Aston indicate that manganese alone in steel rather lessens than hastens corrosion.

Sulphur.

We are convinced that, of all the metalloids commonly present in steel, sulphur, especially when present in abnormal amounts, is the most harmful from a corrosion standpoint. It exists as sulphides of manganese or iron, and our experiments show that in *non-copper* steels as the sulphur increases up to .18 per cent. corrosion is hastened.

Phosphorus.

Although it is undoubtedly true that by increasing the phosphorus content of steel the resistance to sulphuric acid is lowered, yet our work indicates that whatever slight influence it may have in atmospheric corrosion is rather beneficial than otherwise, especially when the phosphorus has been added to the steel.

Silicon.

Silicon in the small amounts normally present in open hearth and Bessemer steels is innocuous. However, experiments made by adding silicon in the amount of .15 per cent. and .30 per cent. show that the corrosion rate is distinctly increased by silicon in these amounts.

Copper.

It is quite generally conceded if copper is properly added to molten steel to the amount of approximately

.25 per cent., the life of the steel under atmospheric conditions is greatly increased. While definite figures from actual losses on weighed test pieces indicate that this increased life is approximately 100 per cent., we are of the opinion that this figure is low. We have reached this conclusion from observations of copper-bearing steels after several years' exposure. It appears that the rate of corrosion of copper-bearing sheets lessens as the time of exposure increases, and that the loss during the first six months' exposure is greater than during subsequent periods.

Any unprotected iron or steel will develop a thin film of rust in a few minutes when exposed to moisture and oxygen. This oxide film is electro-negative to the underlying metal and will stimulate further corrosion. Moreover, the physical characteristics and texture of this rust film are very important factors in governing the rate of corrosion of the metal. The rust formed on copper-bearing steel is dark brown, closely adherent and smooth, and if it does not really act as a protector to the underlying metal it is at least much less an accelerator than is the rust on a normal steel or iron, which is a limonite red in color, rough, loose and spongy in character. That the latter holds water to a greater extent is strikingly demonstrated by examining sheets which have been exposed for several months, both with and without copper, immediately after a rain. Copper-bearing sheets dry very quickly, while the loose, spongy rust on the sheets without copper holds the moisture for a considerable time, allowing corrosion to proceed for several hours after it has ceased on the copper alloy sheets.

While the beneficial influence of copper in steel and iron is most marked under atmospheric conditions, investigations under soil, water and other natural conditions are indicating superiority under these latter influences as well.

Summary.

To summarize conclusions from our work up to the present time: The influence on corrosion of carbon, manganese, phosphorus and silicon in the amounts normally present in properly made steels and irons is practically negligible. In a steel without copper, a high sulphur content stimulates corrosion. A copper content of .25 per cent. materially increases the life of steel and iron, and the harmful effect of sulphur up to at least .14 per cent. is neutralized by .25 per cent. copper. More copper, up to 2 per cent., gives little, if any, additional benefit. Lesser amounts than .25 per cent. have great influence in lowering the corrosion rate. A content of .15 per cent is in most cases quite as good as .25 per cent., and tests now under way prove that much lower amounts, down to as little as .04 per cent. and .06 per cent., while not giving the best results, are remarkably superior to normal steels carrying only the usual traces of copper.

Careful study is being made to determine definitely, if possible, the mechanism of the reactions which take place by alloying copper with steel and iron, and which will explain the remarkable beneficial influence of the copper content. We hope that this information will be available for a subsequent paper. (Applause.)

President Gary: Mr. Buck's paper will now be discussed by Dr. Allerton S. Cushman, President of the Institute of Industrial Research, Washington, D. C. In the case of Dr. Cushman the five-minute rule does not apply. Dr. Cushman is to have all the time he desires.

RECENT PROGRESS IN CORROSION RESISTANCE

Discussion by Allerton S. Cushman

President Institute of Industrial Research, Washington, D. C.

I wish to make a few remarks by way of preface to my written discussion of Mr. Buck's paper. Everything that I shall say is offered simply as a discussion of a metallurgical point of great interest, about which it seems to me there is room for an honest difference of opinion. Metallurgy, I am sure you will all agree, is one of the most complex of all the arts that have been practiced by mankind since his emergence from the Stone Age. Such a sweeping conclusion as has been arrived at by Mr. Buck and his collaborators, if proved true, will have a most profound influence upon the future of the iron and steel industry. The growing demand for rust-resistant metals, if copper is indeed to be the cure-all, will result in the product of the open hearth furnace becoming infected with copper. Once copper finds its way into commercial scrap, it can never be eliminated again by any known metallurgical method; the manufacture of pure iron will become a matter of increasing difficulty as the years go by. Those of us who believe in purity as the standard of excellence will find it increasingly difficult to reach this standard.

I have ventured to take vigorous exception to the findings and conclusions of Mr. Buck and his collaborators, but I wish emphatically to state that nothing I shall say has the slightest personal feeling in it. I, for one, can differ with colleagues with respect to metallurgical problems without losing personal respect for those with whom I am not in agreement. I believe Mr. Buck and his associates to be really convinced that they are in the right, and, therefore, even if they are mistaken, they must

be credited with honestly endeavoring to make a contribution to modern metallurgical art.

Mr. Buck's paper has presented to you one side of a controversy which has been going on in this country for a number of years. Mr. Buck states his opinion that it is unfortunate there should be any difference of opinion on these questions; that there has been an undue adherence to theory without practical demonstration of the value of the theory; that there has been a reprehensible adherence to a particular class of product with which the investigator may be interested financially or otherwise; that too much confidence has been placed in accelerated tests; that the fact has been lost sight of that, even under the best practice, heats below the average are manufactured in all classes of products, with the consequent danger of drawing conclusions from comparing a good heat of one type with a poor heat of another; that it has been customary to draw conclusions from results obtained under peculiar conditions which may or may not be representative.

With some of these statements I am in complete accord, but I do not agree that it is unfortunate that these important questions should be debated and that all parties at interest should have a right to analyze and discuss conclusions based upon tests. It is my belief that if these subjects under debate are finally settled the court of last resort must be the unbiased consumer and not the producer of these various types of metal. "Ask the man who owns one" is the best of commercial slogans. When Mr. Buck selects the word "reprehensible" to characterize partisan zeal he has thrown a boomerang which has a habit of returning to its source.

Testing Is a Complex Problem.

The testing of sheet metals and wire to determine comparative resistance to corrosion is a complex problem in which many variables, some of them quite unknown to us, may play an important rôle. In my own experience

of corrosion problems which have held my close attention since 1904, I have become convinced that tests, like statistics, can be made to prove almost any thesis which it is desired to prove.

The effort to substantiate a point of view may amount to riding one's favorite hobby-horse furiously about without realizing or caring that the other fellow's hobby-horse also has its backers and admirers. I am not afraid to confess my own proneness to fall into this error, but I have attempted to overcome it; and as the years have gone by I have become more conservative with regard to publishing results of private tests which have not been checked up by engineers representing the great consuming interests. Purely partisan evidence is not convincing, and I think one would be wise to reserve judgment in matters of controversy involving metallurgical conclusions of great moment until the evidence is all in.

If I understand Mr. Buck's purpose in the presentation of his tests, it can be boiled down to very simple language. In short, it is this: We are asked to believe that the accidental occurrence in, or the deliberate addition of two-tenths of one per cent., more or less, of copper to any steel will confer upon it valuable properties in corrosion resistance, to the extent of increasing its period of usefulness many times over. In my opinion, Mr. Buck's tests on which he bases his conclusions are open to criticism both in their conduct as well as in the interpretation of the results obtained. I myself have under supervision quite as extensive and comprehensive tests of full-sized sheets, corrugated and plain, which have been exposed for a longer period, and which differ widely both in results and in their interpretation from those presented here today. I have not as yet published these tests for the very reason that I prefer to await the conclusions to be obtained in tests in which the representatives of the consuming interests will have the predominating voice.

Since Mr. Buck has published and republished his

own tests and has submitted his conclusions for discussion here, it is no more than just that I should be permitted to analyze his figures and conclusions. In the two tables, 1 and 2, submitted in this paper, Mr. Buck has fortified his opinions by a group of results showing loss in weight determined on samples two inches by four inches in size. I believe such tests to be misleading, since in my opinion it is not the weight lost by a small sample or a number of small samples, but the way a given metal rusts under all possible conditions of service that must inevitably in the end determine the quality of a type. It is not only a possibility, but it is true that a section of metal which is pitting through very rapidly in segregated areas will lose less weight than one that rusts slowly and evenly all over.

Impartial Testimony.

Mr. Buck himself has warned us against placing much confidence in accelerated tests, but granting, for the sake of argument, that this method of presenting results has weight, why should not the conclusions have been checked up by independent engineers? The representative of a great consumer, Mr. J. L. Campbell, Engineer of Maintenance of Way of a well-known railroad, conducted a comprehensive series of tests under varying conditions on a number of different types of iron and steel. The results of these tests can be found published in *Engineering News* of July 30, 1914. The tests were conducted on test pieces two inches wide and two to three inches long. In four of the five series of results published the coppered steels lost more weight per cent. in twelve months' exposure than the ordinary non-copper bearing steels with which they were compared. I submit that if Mr. Buck's results are to be taken as final, and if also Mr. Campbell's results are to be accepted, there exists a contradiction here which, before any fair-minded jury, would throw the entire data out of court as being inconclusive and unreliable. If I might be permitted to use my imagina-

tion in making an analogy which covers this form of testing and reporting results of tests, it is equivalent to the attempt to determine whether a particular breed or type of dogs is courageous or cowardly by purchasing in the open market a certain number of puppies representing the breed and hanging them up by the tails to determine what percentage of the unfortunate individuals squealed. Upon such data as this learned discussions could be produced as to whether or not that particular breed of dogs was a courageous one. As a matter of fact, the only way that we can form opinions about such things is by observance of dogs in the long run and by the reputation of the breed which it has made for itself over a long period of years. However, in Table 2 of Mr. Buck's paper the relative weight losses are not alone depended upon, but are checked up by counting the number of holes which appear after an eight months' exposure of his test pieces at Scottdale, Pa. Now, if Mr. Buck's results as reported in this case can be repeated and checked up by unbiased investigators they would be of some weight, as no one wishes to buy sheet metal which in a thickness of 27 gauge is capable of being pierced full of holes or reduced to a condition of open lacework under weather exposure conditions in the remarkably short period of eight months. Such results are astounding to me. I have had, among many others, 26-gauge samples of the most ordinary type of non-copper bearing Bessemer steel exposed under the atmospheric conditions of a densely populated mill town which has not as yet begun to combat the smoke nuisance, for sixteen months before the first hole appeared in any of a large number of full-sized corrugated sheets, in spite of the fact that some of my test sheets had been left in the original black, while others for comparative purposes had been first pickled in acid in the usual way. I submit herewith photographs showing these tests.

In order to supplement these atmospheric corrosion tests I adopted the expedient of exposing similar sheets

FIG. 1.

FIG. 2.

Fig. 3.

of different types of metal to a more severe test. This was done by bending up the edges of flat non-corrugated sheets so as to make of them shallow pans. These pans were filled with coal slack cinders and exposed in a horizontal position so that the rains could descend upon them. The results are given in the accompanying table. They are no more conclusive than Mr. Buck's tests. This point I wish particularly to emphasize. But it can be reasonably claimed that if the coppered basic steel was the best material amongst the great number of test pieces which I was investigating, they should have confirmed Mr. Buck's results. I give them here for what they are worth, in the belief that when independent engineers have had time and opportunity to thoroughly study these questions they will meet with a great preponderance of similar results.

Cinder Pan Corrosion Test.

Sheet No.	Material.	Sul.	P.	C.	Mn.	Cu.	Ni.	Condition after 9 months
85	Bessemer Steel	.038	.094	.012	.36	.016		15 holes
108	Basic Coppered Steel	.028	.008	.10	.19	.26		6 holes
169	Pure Basic O. H. Iron	.020	.004	.012	.008	.032		Sound
123	Pure Basic O. H. Iron	.029	.006	.012	.023	.024		1 hole
127	O. H. Nickel Alloy	.020	.007	.010	.037	.036	.16	5 holes
126	O. H. Copper Nickel Alloy	.019	.009	.010	.015	.23	.26	6 holes
170	O. H. Copper Nickel Alloy	.027	.006	.010	Trace	.17	.20	Sound
121	O. H. High Nickel Alloy	.024	.004	.010	.015	.028	1.00	Sound

When as a government official I began the study of corrosion problems in 1904, there was great complaint in regard to the way that modern steels suffered from rapid corrosion. The past decade has seen progress made in many lines, and the steel industry has not stood still. I call attention to the fact that, comparatively speaking, the use of the acid-lined convertor, both Bessemer and open hearth, has decreased, while the growing use of the basic open-hearth furnace has led to greater refinement in steel products, and, above all, a greater control of the elimination of harmful impurities in many types of metal.

Products Now Better.

I have no hesitation in saying that, led by the extremely pure iron which it is now possible to manufacture in the open-hearth furnace, nearly all grades of steel are superior in rust-resisting quality to those which were offered ten years ago. Products and brands are more standard, or less variable in analysis than they used to be. Also they are much purer with respect to the well-known impurities and much better degasified, showing that our operating departments are taking more care with the products than was formerly the general rule. I make this statement quite independently of whether the pres-

ence of a small fraction of copper in steel is beneficial or whether it is not. To my mind, the great danger in the coppered steel idea is that copper can be used to put the stamp of excellence on a product that may or may not be carefully made. Mr. Buck in his paper sounds the warning that the benefits he claims accrue only if the copper is *properly* added to molten steel. Two-tenths of one per cent. of benzoate of soda has been used to preserve and make salable very bad tomato catsup, but its presence cannot turn bad and dirty stuff into good and clean food. In my opinion, precisely the same thing is true of two-tenths of one per cent. of copper in steel.

If the tests under my supervision had indicated that copper was beneficial to carefully made pure basic metal, I should have advised the manufacturers of pure iron to put the copper in. The fact that it costs, in some parts of the world at least, more to keep copper out of steel than to put it in shows the easier way. In this respect, it is interesting to quote from Mr. J. L. Campbell's paper already cited, who says:

> Perhaps the most significant figures are those showing the relative corrosion of samples Nos. 2, 3 and 4, as they are of the same grade of steel, made by the same manufacturer, and are presumably identical in quality, the difference in copper content excepted. In regard to the addition of the copper, we quote from the letter of the manufacturer as follows:
>
> "In regard to the addition of copper, would say that the heats are made up as far as possible with copper scrap and any deficiency in the copper content is made up by adding the requisite amount of metallic copper to the bath in the open-hearth furnace about fifteen minutes or half an hour before tapping. The copper, therefore, has ample opportunity to become evenly distributed in the steel, particularly by the mixing action which takes place when the steel runs from the furnace into the ladle."

I believe that the real reason of any improvement which may have occurred in the effort to introduce cop-

per as a normal constituent of steel lies in the greater purity, better degasification and decreased segregation of the modern material.

I feel it necessary, as a metallurgist who has given a great many years to the study of the effect of the various impurities as they may or may not influence the resistance to corrosion of a typical metal, to discuss Mr. Buck's statements under his separate headings.

Carbon.

Mr. Buck states that although there has been no attempt made to determine directly the carbon influence, it seems that in the low ranges present the carbon has little influence and that this is indicated by a study of the tables which he has given with his paper.

As a matter of fact, a great deal of work has been done by a number of metallurgists in this country and in Europe in the study of the effect of carbon on corrosion resistance. Some authorities hold that carbon, inasmuch as it will allow hardening, will act as a protection, provided it is combined with the iron and uniformly distributed. As a matter of fact, however, it rarely is perfectly combined with the iron and uniformly distributed, as the microscope readily shows, and segregation in the cooling of impure molten metal is always an important factor. In our own practice we believe carbon to be deleterious on account of the fact that it is more difficult to properly degasify the metal while carbon is still undergoing oxidation in the process of burning out. I believe that Mr. Buck has followed a good example in limiting his carbon content from .02 to .14 per cent., with the accent on the minimum side.

Manganese.

Mr. Buck admits that some metallurgists hold the theory that a content of manganese is detrimental to steel in its corrosion resistance, but he does not agree with the theories advanced nor has he observed the

slightest evidence or proof that such claims are justified. Nevertheless Mr. Buck acknowledges that manganese combines with sulphur, forming manganese sulphide, which exists in isolated patches but which he holds is at best only a feeble conductor of electricity and as such should stimulate corrosion to only a slight extent, if at all. He says that it is possible that these patches of manganese sulphide when they occur at the surface of the steel, or as they become exposed by the wasting of the steel, may become oxidized.

Now, venturing to differ from Mr. Buck, I submit that in the production of pure iron the manufacturers do not aim to make material containing patches, and it is this very patchwork condition which existed in the older, segregated, carelessly made steel which has had our most earnest effort in the overcoming. We believe that the consumers of this country are not in favor of patchwork metals, or metals containing patches of ingredients which may contribute to the wasting of the steel to however slight an extent. As a matter of fact, corrosion is governed by a variable number of slight effects, all of which are important. Mr. Buck argues that this patchwork condition is due to the presence of sulphur and not to the presence of manganese. This is an ingenious truism such as the saying that it takes two to make a quarrel. I hold, however, that it is better to use the utmost endeavor to eliminate both the manganese and the sulphur, with the advantage on my side of the argument that it is an easier metallurgical accomplishment to effect the total elimination of manganese than the total elimination of sulphur. But Mr. Buck wants to eliminate sulphur to the highest degree possible, but does not want to eliminate maganese.

In his comprehensive book, "The Corrosion of Iron and Steel," Alfred Sang, on page 84, states:

Dr. Charles B. Dudley (for many years associated with the Pennsylvania Railroad) discovered, some years

ago, that segregated manganese formed centers of corrosion, and it is a generally accepted fact that steels high in manganese are peculiarly liable to oxidation; if the proportion is small and uniformly distributed the effect is inconsiderable. The effect of manganese is corroborated by many reliable authorities.

Mr. Sang then proceeds to give a list of these authorities. It is true that he points out that if the proportion is small and uniformly distributed the effect is inconsiderable, but Mr. Buck bears witness to the lack of uniform distribution within his range and deliberately admits a condition of isolated patchwork. To my mind no further argument is necessary.

Sulphur.

With regard to Mr. Buck's opinion about the influence of sulphur, I am glad to say that I find myself for once in complete agreement with him, and feel no doubt that in his laudable drive against sulphur in the products under his charge he has been working in the right direction.

Phosphorus.

With regard to phosphorus, there is little accurate data as to its effect upon resistance to corrosion. I myself in a paper delivered before this institute some years ago pointed out that nearly all the ancient irons which represent the survival of the fittest were remarkably pure with respect to every element with the single exception of phosphorus. However, I do not feel that any beneficial effect that it might possibly have has yet been proved in modern practice.

Silicon.

Mr. Buck claims that silicon present in the amount of .15 per cent. and .30 per cent. leads to a distinctly increased rate of corrosion.

I am not prepared to question the accuracy of this statement; it is in effect but one more argument for purity.

Copper.

Mr. Buck states that it is quite generally conceded if copper is properly added to molten steel to the amount of approximately .25 per cent. the life of the steel under atmospheric conditions is generally increased. This is, of course, on its face, an incorrect statement. I for one do not concede it, and there are a great many investigators who have published in the technical press of the world who agree with me. In addition to this there is a great body of perfectly unbiased investigators who feel that the point has not yet been proven one way or the other. I do not hesitate to state that no such claim is justified on any basis of unbiased evidence. Mr. Buck says: "We have reached this conclusion from observations of copper-bearing steels after several years' exposure." I may reply to this that we have reached quite the opposite conclusion and that we believe any improvement noted by Mr. Buck is due to a better degasification and less segregation than in the ordinary steels which he has been using for comparative purposes.

The statement that the rust formed on copper-bearing steel is dark brown, closely adherent and smooth, is only partially true. I have noted a number of test samples of copper-bearing steel which showed just such an excellent condition as Mr. Buck refers to, but, on the other hand, I have seen a great number of specimens of copper-bearing steel, especially those made in the acid processes, which show the limonite red, rough, loose and spongy character of rust to which Mr. Buck refers. Almost invariably the pure irons as free as it is possible to get them from copper show the dark brown, closely adherent, smooth surface which seems to be characteristic of all properly degasified basic open-hearth metal. As a result of my observations of numerous tests extending over a great

number of years I must emphatically disagree with the statement put forth by Mr. Buck covering this particular point. Mr. Buck has stated that it is his belief that since copper is electro-negative to iron when it is properly mixed and incorporated with it, it reduces the tendency to corrosion by lowering the difference of potential between the metal and the loosely adherent rust or oxide. If this is true, why, may I ask, does not silicon also, in the amounts from .15 to .30 per cent., show a similar effect, since silicon is also a strongly electro-negative element? But, as a matter of fact, as Mr. Buck claims, the addition of silicon in this range increases the tendency to corrosion. Such metallurgical arguments as these advanced by Mr. Buck cannot be accepted on their face, and when Mr. Buck sums up that the beneficial influence of copper in steel and iron is most marked under atmospheric conditions as well as under soil, water and other natural conditions, I must claim my right to utterly disagree with him not only from the standpoint of the theories he has advanced, but also as the result of close application to the study of numerous carefully planned tests extending over a number of years.

Weather Tests Irrational.

I submit that, in spite of the fact that we are all forced into undertaking weather exposure tests of uncoated sheet metals, such tests are irrational, inasmuch as no one yet uses any kind of iron or steel in an uncoated or unprotected condition, except in a few rare instances in which the conditions of service do not permit of protective coatings. If we are to make such irrational tests, however, I submit that the test pieces should not be pickled or sand-blasted or otherwise treated by special annealing or cold rolling, or by any other method, but should go on test as nearly as possible in the condition that a prospective customer would be likely to buy similar sheets. If any other method than this simplest one is followed, a string of variables is introduced that could easily keep

many of us so-called experts and our descendants arguing over the results until the crack of doom.

I submit also that 26- and 27-gauge sheets are too thin to yield fair comparative results under varying weather exposure conditions. I have never been able to get even the cheapest and most ordinary steel sheets to rust through in the same length of time in which Mr. Buck's best analysis sheets failed, although I have had them out under very severe conditions of exposure. I am therefore led to the belief that the tests described are not conclusive.

At my original suggestion, the Corrosion Committee A-5 of the American Society for Testing Materials is about to undertake a series of systematic weather exposure tests on large corrugated sheets of 16- and 22-gauge iron and steel of all types now available in the open market. These sheets are not to be pickled and only a portion of the heavier gauge are to be sand-blasted. Until these authoritative and unbiased tests can be reported on, it is my belief that such sweeping claims as Mr. Buck has made in his paper are quite unjustified. My own opinion, based on what I consider the most reliable data yet available, is that in metals, as in food, purity is the safest criterion of excellence. (Applause.)

President Gary: The discussion of Mr. Buck's paper will be continued under the five minute rule by Messrs. J. O. Handy, W. H. Walker and J. S. Unger, who will please speak in this order without further introduction.

RECENT PROGRESS IN CORROSION RESISTANCE

DISCUSSION BY J. O. HANDY

Director of Chemical Laboratories, Pittsburgh Testing Laboratory
Pittsburgh, Pa.

While it was known in a general way, previous to Mr. Buck's researches, that copper exercised a retarding influence upon the corrosion of steel, this knowledge was based on only a very few experiments made with steel higher in carbon than the steel of which sheet roofing, etc., are made.

Mr. Buck's work has established beyond any question the superior corrosion resistance of low carbon steels containing copper. He has shown clearly that either basic open-hearth steels or Bessemer steels are made more than twice as durable under weather exposure conditions by the addition of 0.25 per cent. of copper.

In the course of experiments which Mr. Buck and I have made, it has developed that basic open-hearth steel containing as little as 0.04 per cent. copper is as resistant to corrosion as basic open-hearth "pure iron" containing the same amount of copper.

When the amount of copper is still further decreased so that it falls below 0.03 per cent., we know that in the case of either basic open-hearth or Bessemer steel or basic open-hearth "iron," containing the usual amounts of sulphur, the influence of copper is lost and they all corrode very rapidly, the rates being in the order of their sulphur content. This fact seems to establish beyond any question that copper is a controlling element in preventing the corrosion of "iron" and steel.

HOW DOES COPPER RETARD CORROSION?

It is interesting to speculate as to the cause of the efficiency of copper as a rust retarder in steel or iron.

We feel sure, from our researches, that the oxygen content of the steel, as shown by the Ledebur test, is not diminished by the addition of copper, nor do we believe that dissolved oxygen or oxide is the controlling factor in steel corrosion.

We feel certain that in some way the accelerating effect exercised by sulphur upon corrosion in steel is almost entirely inhibited by the addition of copper. A most probable theory is that copper unites with sulphur and the compound dissolves in the steel itself.

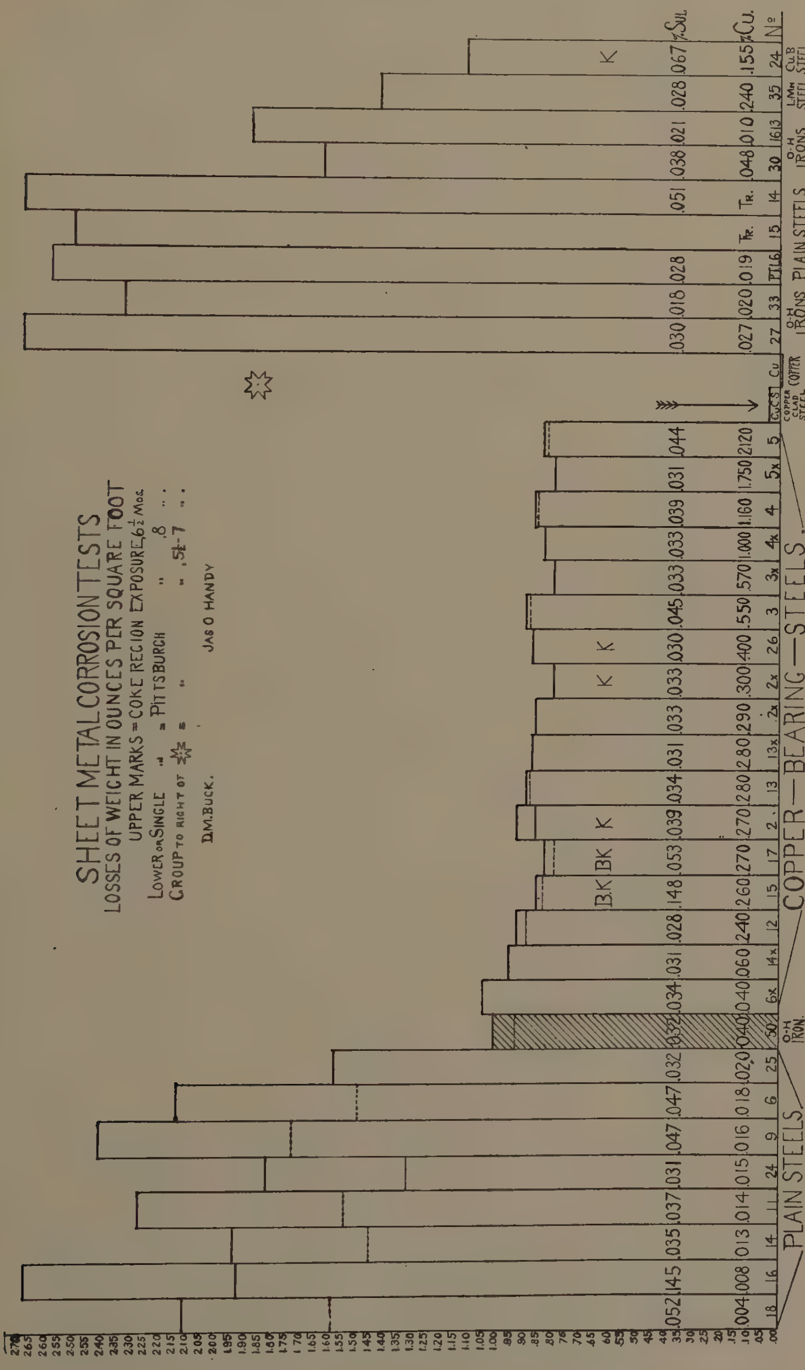
Sulphide of copper is not as readily oxidized as sulphide of iron or sulphide of manganese, and copper itself is extremely weather resistant. The steel, therefore, is far less readily oxidized than when only sulphides of iron or manganese are present in the steel.

This suggests the idea that copper may now be intentionally and intelligently used to combine with sulphur in steel, and to add to the steel other valuable qualities beside corrosion resistance. The ideal, of course, is not only corrosion retardation, but corrosion prevention.

Tests and Their Results.

Exposure tests made at the Pittsburgh Testing Laboratory have shown that copper and copper-clad or copper-covered steel resist the Pittsburgh climate perfectly. We find no material loss of weight after eighteen months' exposure, while, during that time, all of the plain irons and steels have nearly disappeared, and the open-hearth irons and the copper-bearing steels have undergone large losses of weight by corrosion.

Now that it has been shown that the electrolytic theory of corrosion does not prevent basic open-hearth "irons" low in copper from corroding as rapidly as plain steel, and as it has also been shown that Bessemer steel high in phosphorus and sulphur, but containing 0.25 per cent. copper, is even more weather resistant than copper-bearing basic open-hearth "pure iron," we ought not to be afraid to test rigidly the theory that copper-covered steel


SHEET METAL CORROSION TESTS
LOSSES OF WEIGHT IN OUNCES PER SQUARE FOOT
UPPER MARKS = COKE REGION EXPOSURE, 6½ MOS.
LOWER OR SINGLE " = PITTSBURGH
D.M. BUCK.
JAS O HANDY
PLAIN STEELS
O-H IRON
COPPER—BEARING—STEELS
COPPER CLAD STEEL
COPPER
O-H IRONS
PLAIN STEELS
O-H IRONS
L-MN STEEL
CUB STEEL
%SUL.
%CU.
NO.

will corrode rapidly because copper is electro-negative to iron. I refer to copper-covered steel in which the copper covering is welded to the underlying steel. Our own exposure tests show that such material is as durable as copper itself, except at sheared edges, and at these points there is no evidence of more than the ordinary corrosion of exposed steel.

By the exercise of sufficient mechanical ingenuity in manufacture, I feel sure that perfect copper-covered steel sheets can be made, and that they will be a very valuable material for the manufacture of roofing, culverts, etc.

The first lantern slide shows the great superiority in corrosion resistance of copper-bearing steels and open-hearth "irons," when compared with plain steels or plain open-hearth "irons." The slide shows clearly that there is no material difference between plain steels and plain open-hearth "irons" containing less than 0.03 per cent. copper. Both materials corrode with great rapidity. The critical percentage at which copper begins to control the corrosion of steel is between 0.03 per cent. and 0.04 per cent. The difference is very striking. The corrosion rate is 100 per cent. higher in the case of steels or "irons" containing less than 0.03 per cent. copper than it is in the case of those containing over 0.04 per cent. of copper.

The slide shows graphically that in a more impure atmosphere, the plain steels corrode much more rapidly than they do in purer air, while the copper-bearing steels do not show any material difference.

The marked influence of sulphur on the corrodibility of the plain steels is shown most clearly by the diagram. The steels highest in sulphur failed first.

It is a very striking contradiction of the "pure iron" theory to find that by cutting down the copper impurity (?) too far (i.e. below .03%), the metal, instead of becoming more resistant to corrosion, drops abruptly to less than 50 per cent. of its former value. The theory requires revision. (Applause.)

RECENT PROGRESS IN CORROSION RESISTANCE

DISCUSSION BY WILLIAM H. WALKER

Professor of Chemical Engineering, Massachusetts Institute of Technology, Boston, Mass.

We have listened to a very interesting paper in which Mr. Buck has shown that when copper is properly added to steel it produces truly remarkable results. It seems to me that his conclusions are demonstrated by the photographs which were shown. Dr. Cushman has explained to us that he has not been able to get the same results.

Mr. Buck states as one of the causes to which may be attributed the fact that, after years of research, we are not yet in full accord as to the factors which control corrosion, "An undue adherence to theory without practical demonstration of the value of the theory." I would like to paraphrase this to read "An undue emphasis on one corollary of a theory to the complete exclusion of other equally important factors." The electrolytic theory, on which is based the modern conception of the corrosion of iron, predicates this chemical reaction:

Metal + water = hydrogen + metal-hydroxide.

Here are four factors, all of great importance, and of which each one may, under certain conditions, become controlling. But some worthy exponents of the electrolytic theory have considered only the first, namely, the metal, and have ignored the influence of the others, especially the hydrogen and the metal hydroxide. This has led to erroneous conclusions regarding the important factors which accelerate and retard corrosion, which have been unfortunate in their results.

Taking the case of iron, the electrolytic theory assumes that at certain points the iron passes into solution

in the water, and at certain other points an equivalent amount of hydrogen plates out. If there exists on the iron a speck of mill scale, or any other electrical conducting material on which hydrogen can deposit easily, a tiny electric cell is set up and the action proceeds at a rapid rate. In general this assumption is entirely correct. But some enthusiastic disciples of the theory, and I was one of them, made the wholly unwarranted assumption that every ingredient in iron or steel which was not metallic iron itself, would function in this way; and hence the conclusion that the purer the iron, the freer it would be from such electrolytic poles, and therefore the slower it would corrode. But here is where we strained the electrolytic theory beyond its elastic limit. We paid no attention to the effect which these ingredients, not iron, might have on the solution pressure of the iron, or upon the depolarization of the hydrogen, or the character of the iron hydroxide formed. In the first place, to be accelerators of corrosion these metalloids, as we call them must be good conductors of electricity; and this we now know is not the case. Second, to be effective they must be segregated into individual particles—not alloyed with the iron; and generally they do not so exist. Third, and very important, not only must the hydrogen be plated out on such points, but it must here easily depolarize; that is, unite with the oxygen in the surroundings and disappear so that more hydrogen may deposit. In other words, the so-called impurities in iron and steel are not the active factors we at first thought they were, and eliminating these impurities has not brought the result which the theory at first led us to expect. We considered but a part of the theory, not the whole.

Our disappointment in the matter of results has, however, been relieved by the wonderful effects obtained by alloying with the steel a very small amount of copper. We have, for a number of years, carried on at the Institute a large amount of investigation work upon this copper-steel, both in the laboratory and in the field, and

we can substantiate the results which Mr. Buck has obtained and has reported in his paper.

I desire at this time to call attention to the fourth factor of the electrolytic theory, and which has received almost no attention; that is, the influence of the metal hydroxide which is formed on the rate of corrosion. We find that the film of iron hydroxide or "rust" which forms on a plate of copper-steel is much denser and depolarizes much more slowly than does that on any other type of iron or steel of which we know. In field tests this same phenomenon is observed. I have here three plates which have been exposed to the weather on the roof of one of the buildings of the Institute of Technology at Boston for something over a year. They are all from sheets bought in the open market in Boston. No. 1 is a copper-steel containing 0.22% of copper; No. 2 is a pure open-hearth iron and contains 0.04 of copper; No. 3 is a piece of ordinary mild steel. The coating on the copper-steel is dense, closely adherent and depolarizes with great difficulty; that on the plain steel is yellow, loose and granular, and allows the surface of the metal to depolarize easily; the pure iron with .04 copper is obviously between the two.

Regarding theory, let me say in conclusion that we must remember that the object of science is to make known the phenomena of nature and not to answer the question why they are so. If we can establish a principle or theory which will correlate a large number of otherwise unrelated facts, which will help us to explain one phenomenon in terms of another, which will enable us to generalize regarding such phenomena so as to predict results not yet experimentally established, then theory is a helpful and valuable thing. But, on the other hand, if a theory be so used as to obscure a part of the phenomena with which it deals, or if it causes facts inconsistent with it or not explained by it to be ignored, then it becomes harmful, and a hindrance to progress rather than a help. (Applause.)

RECENT PROGRESS IN CORROSION RESISTANCE

DISCUSSION BY JOHN S. UNGER

Manager, Central Research Bureau, Carnegie Steel Company, Duquesne, Pa.

I came here today to listen, not to discuss this paper. I had no idea that I would be called upon to discuss it; but, fortunately for me, while the others were reading and discussing the paper I made a few notes.

The subject is of peculiar interest, as we have two opinions that are almost directly opposite to one another. I do not think the user of a steel sheet is interested as to whether the sheet corrodes in accordance with the electrical theory, the carbon dioxide theory or any other theory. He wants to know what sheet will resist corrosion the longest. He is not going to ask if it contains copper, or if it is a pure iron or steel containing traces of copper. He is going to insist on getting the sheet which, when submitted to a practical service, lasts the longest.

I might say that I have seen the tests referred to by Mr. Buck. On several occasions I visited the test stations at Atlantic City, in the coke region and those at Demmler. I had no other interest than that of a scientific one, so I feel that my opinion in this matter is unbiased by any outside influences. I noticed particularly in examining the sheets on the roof that many of them were badly corroded, very rough to the touch, almost like very coarse sandpaper, and decidedly yellowish brown in color. Other sheets were comparatively smooth, only slightly rusted, and dark brown in color. In making inquiries as regards the composition of the different sheets, I was impressed by this fact: I found sheets on the roof, of Bessemer steel, with approximately one-tenth per cent. phosphorus and .140 sulphur, that had been almost completely destroyed by atmospheric corrosion after ten months' exposure. Similar sheets from the same Besse-

mer blow that had .25 per cent. of copper added, put on the same roof at the same time and exposed to the same weather conditions, were in very fair condition. My own judgment of the matter was that sheets containing a quarter of one per cent. of copper would outlast the others about three to four times.

While making an examination to determine if purity in steel would improve the resistance to corrosion, I found on the same roof, under identical conditions of exposure, sheets of open-hearth steel in which the phosphorus and sulphur were under .04 per cent. Examination of these open-hearth sheets, made without the addition of copper, showed that they had not corroded as much as the high phosphorus, high sulphur, non-copper Bessemer sheets. After the addition of a quarter of one per cent. of copper to each of the steels, I could not detect any difference between the pure basic open-hearth steel and the very impure Bessemer steel. This indicated to me that the small amount of copper added so effectually masked the effect of composition in the steels that the original composition was practically negligible.

The positive and sure way to determine the value of any of these steels would be to do just as Mr. Buck has done. Take the full size, unprotected sheets and put them on a normal roof, placing the different sheets to be examined on the roof at the same time, and after certain regular periods of time make an examination to find which has resisted corrosion the best.

It seems that a very simple way to settle this disputed question once and for all would be for those interested in the production of pure irons, and of copper steels, and those interested in the final use of the same, to get together and make such tests in a practical way, exposing the unprotected sheets to atmospheric corrosion so as to meet real service conditions, and from those results draw positive, definite conclusions.

No one can really appreciate what difference there is between a copper bearing and a non-copper bearing sheet

made from the same heat of steel, without actually seeing it on a roof. I do not feel that the photographs that have been presented this afternoon have done the matter justice. You must get on the roof. You must feel the sheet to see how rough the surface may be and how much it has rusted. You must examine the pitting, observe the rust adhering in flakes to the under surface, note the color of the corroded sheet, and determine the loss in strength from a small strip sheared from the exposed sheet and bent by the fingers.

These are the true indications of the corrosion of the sheet. This I have done, and my conclusion is that the addition of one-quarter of one per cent. of copper to a soft steel, which contains less than .05 per cent. copper, will increase from two to four times the resistance to atmospheric corrosion of that steel, regardless of the process by which it has been made or of what purity it may be. (Applause.)

President Gary: The discussion of Mr. Buck's paper will be closed by Mr. G. H. Charls, Vice-President of the American Rolling Mill Company, Middletown, Ohio.

RECENT PROGRESS IN CORROSION RESISTANCE

Discussion by G. H. Charls
Vice-President, American Rolling Mill Co., Middletown, Ohio

The subject of the corrosion of iron and steel has had my attention for the last ten or eleven years, or ever since the inception and production of pure iron in the open-hearth furnace. I have been very much interested in the discussion because not a day passes without some new phase or requirement of rust-resisting material comes to my attention. It seems proper to say here and now that, in order to make the results comparable in every way, Dr. Cushman has been using the same copper steel that Mr. Buck used, which is identical in every way—or at least it should be.

In referring to the manganese content, there is always the tendency to omit the fact that it unites with sulphur to form the patches of manganese-sulphide, mentioned by Mr. Buck, which obviously accelerate corrosion.

After inspecting hundreds of samples of copper steel exposed to the elements for longer periods than the samples exposed by Mr. Buck, it has been found that copper-bearing steel shows both the light and dark colored rust.

Our investigations prove that a sheet made from a dense ingot produces a dark brown colored rust; sheets made from spongy, porous ingots produce a light-colored granular rust.

Dr. Unger recommends that you base your judgment on the results produced by unbiased investigators. If this suggestion is followed, there is but one unbiased authority mentioned in these discussions whose opinion can be consulted. I refer to the test made by J. L. Campbell, a well-known railway engineer of El Paso, Texas, mentioned in Dr. Cushman's paper. Mr. Campbell was

first led to believe by his tests that copper added to steel made it more durable, and so expressed himself. However, after he had conducted these same tests for a longer period the results proved just the opposite—namely, that plain steel to which copper had not been added was more rust-resistant than steel in which the copper varied from .20 to 1.00 per cent. Therefore, if Dr. Unger's suggestion is followed, and if we rely upon experiments made by disinterested parties, we can only come to the conclusion that copper added to steel does not increase its resistance, but rather accelerates corrosion.

Co-operation should encourage a free discussion of questions on which there is a sincere difference of opinion, especially when such discussions enlighten and tend to raise the quality of American products.

It is, indeed, very gratifying to observe that Mr. Buck has proven so conclusively in his second table that 27 gauge pure iron has at least twice the life of steel. No one can justly accuse the author of this paper of being an ardent advocate of pure iron. Even I am unwilling to admit he was biased in favor of pure iron.

This truth becomes more remarkable when you are informed that 27 gauge black pure iron is not even advocated by its producers, because it cannot always be rolled satisfactorily. This is explained by the fact that pure iron is so soft, so ductile and welds so readily, the 27 gauge sheets stick fast together in rolling and are often damaged when torn apart.

Through the courtesy of Mr. Buck, a sheet taken from this lot which was to be tested came under my observation. In measuring the thickness of this sheet it proved to be nearer 28 gauge than 27 gauge in many places, due to the difficulty of obtaining a uniform gauge in rolling such light material. It is, therefore, doubly gratifying to note the splendid record made by this light-weight 27 gauge pure iron, sand blasted or pickled (before it was tested) to almost a tissue paper thickness, made under protest and against the advice of its producers and in

every way unworthy of being considered a representative product by any fair-minded person.

If, under such adverse conditions, pure iron outlasts steel two to one, it must be graciously conceded that the claims made for this product have been thoroughly substantiated and sustained. This would be very welcome information to the thousands of purchasers of pure iron if they were not already aware of the intrinsic value of this product and its superiority to steel from the standpoint of resistance to corrosion.

However, I am glad one who is not an advocate of pure iron has made clear to the world at large that all previous criticisms and efforts to belittle the serviceability and durability of pure iron have been due either to prejudice or a lack of any knowledge of the subject. (Applause.)

President Gary: Is there any further discussion under the five minute rule? (After a pause) We stand in recess until seven o'clock this evening, when the annual dinner will be held in the grand ball room.

EVENING SESSION

The annual dinner was held in the Grand Ball Room of the Waldorf-Astoria, Judge Gary, President of the Institute, acting as Toastmaster.

After the dinner had been partaken of, Judge Gary called for order and said:

Mr. Farrell is not with us tonight. He is out on the broad Pacific. But he is thinking of us, as is shown by the following telegram just received from him. It is dated Pacific ocean and is sent by wireless. The message says: "Wish you successful meeting Institute. Kindest regards yourself and members. Yours for cooperation. James A. Farrell." I have prepared and with your permission will send to Mr. Farrell the following telegram: "Your message. 450 members Institute at banquet send you affectionate greetings. Gary." (Applause.)

The first number on the program this evening is a paper on the Welfare Work of the Tennessee Coal, Iron and Railroad Company by Lloyd Noland, M.D., Superintendent of the Health Department of that company.

Annual Dinner of the American Iron and Steel Institute, Waldorf-Astoria, New York, May 28, 1915.

WELFARE WORK OF THE TENNESSEE COAL, IRON & RAILROAD COMPANY

LLOYD NOLAND, M.D.

Superintendent, Department of Health, T. C. I. & R. R. Co.,
Birmingham, Ala.

I have the honor of bringing to your attention this evening a brief account of the welfare work now being undertaken by the Tennessee Coal, Iron & Railroad Company.

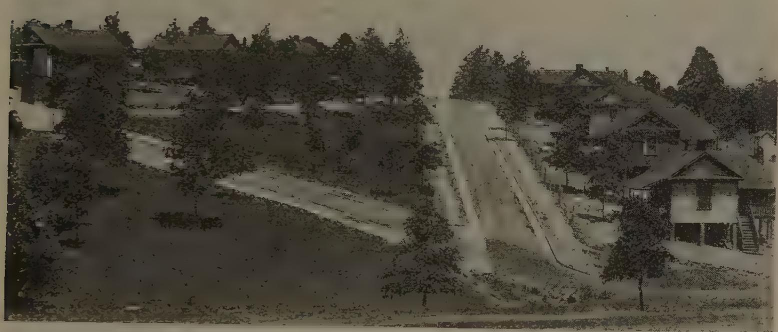
In recent years, the term "Welfare Work" has become familiar to every one, and activities under this head have multiplied at an amazing rate. An exact definition of the term is difficult, and it is hard to determine its limitations; therefore, the subject will be considered in its broadest sense, namely, the conservation and upbuilding of health and strength, both physical and moral, among our employees.

Before taking up the various means by which this is being attempted, a brief statement of the general situation in the Birmingham district is necessary to a thorough understanding of the problem confronting this company.

The Tennessee Coal, Iron & Railroad Company is engaged in the operation of ore mines, coal mines, quarries, blast furnaces and steel plants. These mines and plants are distributed over a wide territory, though by far the greater portion are within a fifteen-mile radius of Birmingham. About 15,000 men are employed in these operations, a little over one-half of whom are negroes. About 34 per cent. of the employees live in houses owned by the company. Of the employees living in company houses, about 65 per cent. are negroes. A working force of 15,000 men with their families represent a population of about 45,000, 66 per cent. of whom live in the cities, towns, villages and countrysides contiguous to the mines and works, in houses not owned by the company.

General view of colored quarters at Fossil.

Many of the houses owned by the company were constructed a number of years ago without much consideration being given to the type of houses built or to their arrangement and location. In recent years, however, much attention has been given to proper house construction, and much remodelling and rearranging has been done in the older groups, while in the more modern groups the houses have been well planned and located. The houses of the modern groups are of three-, four- and five-room types, with running water at every house and with



Colored quarters, Fossil, closer view.

ample yard and garden space, surrounded by good fencing. Attention has also been given to variation in type of construction and variety in the painting of houses. In addition to houses for employees, commissaries, bath-houses, schools, churches and club-houses have been built.

Generally speaking, all welfare work comes under the management of the Department of Health of the company, closely associated with which is the company's Educational Department. For convenience of handling, the Health Department is separated into three divisions, namely: Sanitary, Medical, and Welfare.

Sanitary Division.

The Sanitary Division is responsible for the following: Purity of all water supplies; the care of closets

and the disposal of fecal matter; the collection and disposal of trash and garbage; the cleaning and draining of streets and alleys, including weed and grass cutting; the supervision of all house premises; the elimination of mosquitoes; the inspection of stables and the prompt disposal of all stable manure for fly prevention; the isolation and quarantine of cases of contagious and infectious disease; the supervision of milk supplies, and the inspection of commissaries to insure proper protection and purity of all food supplies.

The company is divided into six Sanitary Districts,

Pure water supply, filtration plant at Docena.

each under the charge of a Sanitary Inspector, with a sufficient force under his immediate direction to carry on the work. Sanitary Inspectors report direct to the Superintendent of the Department, but keep in close touch with company physicians at all points, the physicians acting as local health officers and directing the handling of contagion of any kind. The sanitation of these districts involves so many items that it is impossible to go into all details in the time allowed; therefore, only a few of the more important will be touched upon.

Water Supplies.—As a usual thing all houses are furnished from some general supply with an adequate distribution system to each house. When necessary, this water is filtered or treated at a central plant. Specimens from all general supplies are examined once each week in the company's bacteriological laboratory.

Care of closets.

Feces disposal, septic tank method.

Care of Closets.—The average life of a mining town is too short to justify the great expense of a general sewerage system, therefore some other method is necessary. With us the pail system is in general use, and closets are constructed with a view to adequate ventilation and proper prevention of fly contamination. Pails are removed and clean pails replaced at least twice weekly. Feces disposal is accomplished by means of septic tanks or by cess-pits at isolated points. (The septic tank method will be used exclusively in the near future.)

Mosquito Work.—Mosquito breeding is general throughout this district from the middle of April to the middle of October, and malaria has not only caused many deaths and much illness, but has seriously interfered with the efficiency of labor. By careful drainage of all pools

Mosquito control—undrained swamp. Pretty but dangerous.

and swamps when practical, and systematic oiling of the surfaces of streams and of undrained pools, a great reduction in this disease has been effected. (See chart.)

Fly Work.—Stable manure is, of course, the great fly incubator, though wet trash and garbage also play an

Mosquito control—swamp after proper drainage. Less pretty but safer.

important rôle. In the handling of this problem, all stables are carefully cleaned each morning and removal of manure is required during the day. Manure incinerators have been constructed at each of the large company stables at a very small cost, and manure is burned if not removed promptly. Farmers and others who use stable

Fly control—concreting of stables.

manure now rarely fail in its prompt removal, knowing that the incinerator is ready for use at all times. Covered trash and garbage receptacles are provided at each house, and collection and incineration of trash and garbage takes place at least twice weekly. An enormous reduction in flies has been accomplished by the above methods, and with it a marked reduction in the occurrence of fly-borne diseases.

Medical Division.

The Medical Division is organized with the idea of furnishing medical and surgical care for all employees

Medical dispensary at Wylam.

except those residing in Birmingham proper. The work of this division is divided into twenty districts, each of which is under the charge of a District Physician, who reports direct to the head of the department. These physicians, with their assistants, comprise a force of thirty-five doctors and fifteen nurses, all of whom are employed by the company on a salary basis to devote their entire time to the care of employees of the company and their families. The duties of these physicians and nurses embrace the following:

Physical examination of all applicants for employment;

Physical examination of all school-children, together with frequent inspections of the schools;

Close cooperation with the Sanitary Division in general health work;

The care of all sick and injured employees and their dependents, without regard to the nature of the illness or whether or not injury was received in line of duty.

Medical examination of school children.

The company maintains two base hospitals of eighteen and twenty-six beds, respectively; six smaller hospitals of two to eight beds, and twelve dispensaries. A thoroughly equipped Central Laboratory is also maintained, to which chemical, bacteriological and pathological work is referred by all physicians for assistance in exact diagnosis and treatment. This laboratory also handles work for the Sanitary Division, such as the weekly examination of all general water supplies, the frequent examination of isolated water supplies, the examination

of milk and other food supplies. During the year 1914, this laboratory reported on a total of 3,696 specimens of all kinds examined.

An enormous amount of work is handled by the Medical Division, and every physician is constantly in close touch with the community. The scope of organization enables the employee to have a much higher quality of service than he could otherwise secure, for the reason that facilities are provided for proper examination of all

Ambulance service.

kinds, for careful laboratory work and for consultation covering various specialties; and in addition to this, as the service is always on call, ailments are usually discovered in their incipiency, thus saving much loss of time to the employee and many outbreaks of communicable disease. As against this, many useless calls are, of course, made, but gradually this trouble will be eliminated by proper instruction and education of our people. During the year 1914, there were 129,551 applicants for treatment at the dispensaries, and 84,621 calls were made at the homes of employees.

The expense of the Medical Division is borne partly

by the company and partly by the employees through a system of voluntary contribution. Under this system, any employee living within a certain radius of the works and mines may request that he be placed on the "medical list." The payment of 75 cents per month entitles each employee and his dependents to treatment for any possible ailment. At present, practically all employees living in the zone of this service voluntarily avail themselves of its advantages.

While the Medical Division is doing valuable work, there is one serious drawback to its full efficiency, which is the lack of a large base hospital for the treatment of illness of all kinds, particularly that of a communicable nature. It is impossible to secure ideal results, either from a sanitary or medical standpoint, in the treatment of communicable disease in small and often crowded houses, and the only practical solution is the prompt removal of the patient, as soon as a diagnosis is made, to a hospital maintained for this purpose.

Club-house at Muscoda.

Welfare Division.

The Welfare Division has charge of the club-houses located in various towns; the conduct of courses of cook-

ing, sewing and practical housekeeping for both school-children and adults; the kindergarten instruction of

Instruction in cooking at Edgewater.

children below the school age; home visiting and instruction by social workers and schoolteachers; supervised play at all playgrounds and schools, and supervision of various social organizations, such as Boy Scouts, Camp Fire Girls, Mothers' Clubs, Young People's Clubs, etc.

The scope of work and the influence of this division are rapidly increasing. At present seven well-equipped classrooms for instruction in cooking and sewing are in operation, with a large and enthusiastic attendance of girls and women. Three kindergartens are in operation with an enrollment of over one hundred children, and much useful visiting is being done in the homes of employees, giving opportunity for tactful suggestion and instruction regarding betterment in living conditions.

Educational Department.

The Educational Department is charged with the operation of all company schools. These schools, twenty-

four in number, are maintained or partly maintained by the company in cooperation with the County, and are divided into twelve schools for whites and twelve for negroes, with a total enrollment of 3,311 pupils, under the charge of a superintendent employed by the company.

All sanitary arrangements at schools, as well as systematic inspection and examination of children and the following up of every absentee, are handled by the District Physician in close cooperation with teachers and welfare workers.

The question naturally arises as to what is accomplished by work of this character, and whether the expense entailed is justified. There can be no doubt

Cooking class for colored women at Ishkooda.

but that a workman properly housed and whose family is possessed of home comfort is a better and more steady worker than one living in discomfort and dirt. A clean, well-sanitated town, made up of comfortable homes, most certainly tends to stimulate thrift and energy.

Bath-houses at mines and works, which are coming

Commissary department at Docena.

into very general use all over the country, are a great advance in many respects. There is no question that the daily bath promotes health and energy, and, in addition, has a great effect on the home, for the housewife must have a clean home and a clean family to meet the clean head of the house on his return from work.

Commissaries are a necessity where negroes are

Typical meat market. Note screening.

employed. A clean and well-ordered store tends to better business administration always, and, in addition, teaches a valuable lesson to every customer; also by strict attention to cleanliness and sanitation in the handling of foodstuffs in these stores protection is afforded to the health of the community.

School gardens—health and happiness.

General sanitation is not only a moral responsibility, but a work that pays, for the prevention of disease is always cheaper than its cure. The sickly workman, or the workman with a sickly family, is an expensive investment always. Pure water supplies mean freedom from typhoid and the dysenteries. Proper care of closets and the prevention of soil pollution mean prevention of the fly-borne diseases and of hookworm. Mosquito prevention work means the reduction or elimination of malaria and increased comfort in living. The proper handling of stable manure and of trash and garbage means the reduction of that dangerous pest, the house-fly; and the prompt and efficient handling of contagion means a steady working force, as against a force often torn to pieces by epidemics of various kinds.

The employment of physicians and nurses by the com-

pany insures every workman skilled attendance, together with facilities for exact diagnosis and treatment, such as he could not possibly secure in the usual way. Under this system all conditions are treated, no matter what the ailment, or how contracted. This system not only keeps the standard of health high, but it protects the employee from the overburdening expense so often incurred by sickness in his family, and also protects the more ignorant from the designing quack and patent-medicine faker. However, the acceptance of the company service is voluntary, and the employees' privilege to secure other medical service is in no way abridged.

The value of the work of the Welfare Division partly remains to be proven, but we are convinced that sufficient good has already been accomplished to warrant extension of the work and to give much hope for the future. The

Supervised play.

Educational Department has already proven its value in a practical way by bringing to the service of the company a class of workman impossible to secure unless facilities for the proper education of his children are available.

The employees of this company consist of 53 per cent. negroes, 37 per cent. white Americans and 10 per cent. Europeans. The negro is easily taught and usually obeys advice and instruction. He is easily approached, and, as a rule, is anxious to improve his conditions of living.

White school at Docena.

As against these good qualities, he is lazy and often will not work unless in actual need of food and clothing. In many instances his family is ignorant of the proper methods of preparing food and of the essentials of home economy. The European, as a rule, is eager for instruction of every kind, and is generally sober and industrious.

Colored school at Fossil.

Kindergarten at Edgewater.

He is apt, however, to live in a slovenly manner and to be entirely ignorant of home hygiene.

It has long been realized that the sober, industrious and hardy workman must have properly prepared food, a clean and well-conducted home and a healthy family; therefore, it follows that wives and prospective wives who are ignorant of housekeeping, sewing, cooking and of home hygiene, must be instructed if efficient workmen

Kindergarten circle at Edgewater.

are to be produced. This instruction is being given by our welfare workers to the women, by systematic visiting and teaching in the home, and by the organization of classes meeting at the club-houses and schools. Every girl attending the company schools is required to take courses in cooking, sewing, etc. Social organizations, such as Boy Scouts, Camp Fire Girls, Young People's Clubs, Mothers' Clubs, etc., are organized and headed by these welfare workers and schoolteachers, and proper ideals are carefully instilled at every opportunity.

Schoolteachers and welfare workers reside in cottages maintained for this purpose, which serve as an example to the women of the community of how houses should be kept and run.

Churches are provided for every community, and much is being accomplished through church and Sunday-school work.

Kindergarten instruction prepares the small child for entrance to the schools, and relieves the mother of its care during the morning hours.

Playgrounds for children, and baseball and football fields for the men, are also provided.

The schools are being well attended and their standard is being rapidly improved. Every effort is being made to give practical courses and to secure steady attendance of all children through the eight grades.

When all is said and done, our great hope for the future lies in the younger generation now in our schools, on whom every effort is being directed toward physical, mental and moral upbringing. If our efforts are successful there will be developed in the Birmingham district a generation of healthy, sober and industrious working men and women, adequately equipped to realize and to perform their duties to the community, to their employers and to themselves. (Applause.)

POSTPRANDIAL REMARKS IN RESPONSE TO CALL OF PRESIDENT GARY

PRESIDENT GARY: As noted on the program, and following our usual custom, we will call upon a few members for brief remarks. The list of those to be called upon has been furnished me by the Committee on Arrangements. I suppose that those to be called upon have been notified during the evening that we hope to hear from them. Their remarks will necessarily be limited in time. I wish to remind the speakers that if they take more time than has been allotted to them respectively, they are trespassing on the time of speakers who will follow.

I have pleasure now in calling on Mr. John A Penton, publisher of the *Iron Trade Review*, Cleveland, Ohio. (Applause.)

MR. PENTON: It seems to me that we have heard much here today that should furnish inspiration for those who are directly or indirectly engaged in the iron and steel business, and that ought to give us something to think about after we have gone away from this meeting, something that may well serve as an incentive to the promotion of even better conditions in the industry.

Specifically I refer to the splendid address of our president to which we listened this morning. In the words of a gentleman who is sitting near me, "It was a message to the whole world from the iron and steel men of America."

It sometimes seems to me that we ourselves may possibly not fully realize and appreciate the full significance and importance of this industry in America. According to the last figures of our national government, the value of the products of the iron and steel and machinery plants in this country in the last year of which a record has been published amounts to nearly $4,000,-

000,000. That is an incomprehensible amount of money. It sounds more like a European war debt than anything else. If I remember correctly, it is more than twice the value of the corn crop and four or five times the value of the wheat crop.

As I recall the figures, the value of the iron and steel and machinery exported from the United States last year to foreign countries exceeded $300,000,000. Think what that means in turning the tide of gold toward this country, what it means to the prosperity of our people, what it means not only to those engaged in the industry but to the entire nation.

We have listened with interest and satisfaction to Dr. Noland's paper on the Welfare Work Done by the Tennessee Coal, Iron and Railroad Company, one of the subsidiary companies of the United States Steel Corporation. I understand that the expenditure of the Steel Corporation alone for welfare work since the organization of the Corporation has been upwards of fifty millions of dollars. And fifty millions of dollars expended in such work as we have seen illustrated this evening represents an enormous gain to mankind. Moreover, this work of the Corporation is typical of what is being done by the other iron and steel companies of this country. Last summer I had an opportunity to visit the nothern part of Michigan. Although I have tried to keep track in a general way of this great movement in industrial welfare, I did not really appreciate it until I saw it for myself. I think that comparatively few of us realize the improvement of the character of the homes in which the miners live as compared with the small huts and unpainted houses in which they lived ten, fifteen and twenty-five years ago. I knew the character of the houses and the inconveniences and hardships of life in those sections at that time, for I lived in that part of the country myself. Today in northern Michigan, Wisconsin and Minnesota, the miners live in handsome homes, on streets finely paved, with water, gas and electricity. And the com-

panies offer premiums for the best vegetable gardens and for the best kept homes. Accident prevention, sanitation, hygiene and social service are all subjects to which the employers give attention and on which they spend much money and thought. "Health and safety in mine and mill" is one of the mottoes of the Institute, and it is lived up to in practice. There are great bath houses at the entrance of the mines for the comfort of the miners. I am familiar with the work of the ore boats on the Great Lakes and the work being done by the operating companies for the safety, health and happiness of men on shipboard. Seeing all this, knowing in a general way of such work in all parts of the country, I say with all proper respect that in proportion to the number of people whose lives are touched, no religious body is doing more or better work for humanity than is being done by the manufacturers of the iron and steel business of this country. (Applause.)

It seems to me that the time has about arrived when those engaged in this industry should come into their own. I really believe that we are entering a new day and that the reign of terror, as one of the papers expresses it, has gone by. I believe that in the spirit of cooperation recommended by our president this morning we shall accomplish great things for ourselves and the country. (Applause.)

President Gary: Mr. Edward M. Hagar, President of the Hagar Cement Company.

Mr. Hagar: Speaking as a representative of the cement industry to you representatives of the steel industry, I wish to preface my remarks by assuring you that if I say anything that sounds like criticism of the steel industry I do it with the most kindly feelings, because of my life-long relationship with you gentlemen and because of the kinship of the two industries.

My main purpose in responding to Judge Gary's call

is to raise the question, "How much has been done by the steel manufacturers during the history of the industry to create, by positive educational work, a greater demand for steel products?" I think the answer must be that very little such educational work has been done. By contrast I think it only proper to say a few words as to what has been accomplished and is being accomplished by cement manufacturers to promote the use of their product.

Individually and through their associations, the manufacturers of Portland cement have deliberately proceeded to discover new uses for cement and then spread the knowledge of these new uses among the people. And the results have been both surprising and gratifying. It was the cement manufacturers who went into the subject of concrete roads, and it has been their energy largely that has given the country so many of these good roads. Then take the matter of fireproof construction. The cement manufacturers have shown the people of the United States that this country wastes over $300,000,000 a year through preventable fire losses. The fire loss per capita in the United States is over $3 per annum. In sixteen European countries it is sixty-three cents per capita per annum; in Italy it is only twelve cents. Fire insurance rates in this country average about one dollar per one hundred dollars of insurance, as against ten cents per hundred dollars of insurance in Europe.

In both concrete road construction and in fire-proof building construction the manufacturers of cement are doing a great deal to promote the use of steel. If the manufacturers of steel spent as much money in proportion to the number of dollars of business done to help themselves in the way of discovering and advertising new uses for steel, they would be expending $12,000,000 a year to extend the uses of their own product. That $12,000,000 would represent only a small fraction of a cent on each dollar's worth of business done. We manufacturers of cement have found by experience that we get back with

big interest all the money we spend in this educational campaign.

I would suggest that the American Iron and Steel Institute get into touch with the cement manufacturers, who will be glad, I am sure, to meet and co-operate with members of the Institute in promoting their common interests. (Applause.)

President Gary: Mr. King got hold of the list provided me by the Committee and attempted to erase his name as one of the speakers. Are you willing to excuse him? (Cries from the members, No. No.)

President Gary: I am sorry, Mr. King, but we will have to call upon you.

Mr. King: Judge Gary and Members of the Institute: After this pleasant and instructive day and under the influence of this good dinner and congenial company, it is easy for every one here to become an optimist for the future welfare of the American Iron and Steel Institute. I am one of those optimists, for I have great faith in the future of the Institution. As a director, I would like personally to tell the gentlemen who presented those admirable papers today how much the directors and officers of the Institute appreciate their effort, and what care the directors are taking to keep those records safely and completely, as they believe that in the future many of them will be regarded as text-books and authorities on the subjects treated. Who can estimate the value of the friendships formed at these meetings? We cannot put a financial value on them, but one of the poets has said that friendship is the wine of life and a sheltering tree from the storms of life.

I will close by asking the cooperation of all the members, and particularly of the younger men. I was very glad to see so many young men read those papers today. It speaks well that men of their age could produce such

papers as these are. And I would like to ask your continued support of this Institute in every way to further its interests, and I know you will be repaid very many times in the future. (Applause.

PRESIDENT GARY: It is my pleasure to introduce now Mr. Joseph G. Butler, Jr. (Applause.)

MR. BUTLER: Mr. President, Fellow Members and Ladies in the upper circles: I thank you very much for this opportunity to deliver an impromptu speech which I carefully prepared this afternoon. I think Mr. Schwab ought to have been called on ahead of me.

We have a ministeral association in Youngstown that meets once a week. It is composed of all the Protestant ministers and three Jewish rabbis and two or three of the liberal Catholics. They have at heart the good interests of the town above everything. About three weeks ago they conceived the idea of taking a religious census of the town. They wanted to know just how we stood, how many people were really good Christians and how many were pretty near Christians and how many were on the other side. So they appointed special census takers from each church and they came around to our house. I didn't happen to be home when they got there, but Mrs. Butler was there on the job, and she happened to know this man that was appointed for our street; and he asked her about the family, saying, "Now, I want to know about the servants and everybody connected with the household." "Well," she said, "our cook is a Methodist; our waitress is a Catholic; our chauffeur, well, he is a Scotchman, and, of course, he is a Presbyterian; I am an Episcopalian." "But what is Mr. Butler?" "Well"—she thought a while—"he is a McKinley Memorial." (Laughter.)

I listened during the morning session to three able papers, the first by our honored president, and it is very gratifying for me to feel that an institution, which is

supposed to be only connected with the iron and steel industry, has at its head a man who can produce a paper like that—a state paper, something that will influence the entire country.

I was present when the American Iron and Steel Institute was formed. There were less than twenty-five people present. Our membership now is almost 1,400. Our limit has almost been reached. I am proud to be one of that 1,400. I don't believe that any other club or association in existence compares with this.

I know that we are all eager and anxious to hear from Mr. Schwab, who came all the way from Bethlehem on purpose to talk to us. I met a gentleman who heard Mr. Schwab talk to a business men's association in San Francisco during his recent visit there, and he says, "I want to tell you, Uncle Joe, that Chauncey Depew is not in it with that man." (Applause.))

The last time I was in Nevada, some two or three years ago, Mr. Schwab happened to be there. We all know that he is a very liberal man. I do not intend to make any reference to the McKinley Memorial beyond the little story that I told. Mr. Schwab gave me a very handsome contribution and told me not to mention the amount, and I won't. He did not give me a check for it. We all know he is a very liberal man. With all these shrapnel orders coming in, there is no telling what he will do for his country. (Laughter.) But this time, while in Nevada, as I said before, we took a ride to a mine that he and I have sunk several dollars in. The driver had a couple of broken down horses that had seen better days. When we reached our destination and jumped off the buckboard, Mr. Schwab handed the driver a five-dollar bill. The man looked at the bill and then at Mr. Schwab, and said, "Which one of the horses would you like?" (Applause.)

President Gary: Is Mr. George W. Perkins in the room? (After a pause.) It is a fact that Mr. Schwab

came from Bethlehem this evening to attend this banquet and did not come here to make a speech. But I find his name on the list of speakers and I will introduce Mr. Schwab. (Applause.)

Mr. Schwab: Mr. President and Gentlemen: I came here this evening expecting to enjoy my dinner without the prospect of a speech ahead of me. I thought there should be at least one meeting when the representative of Bethlehem might be exempt. But Uncle Joe seems to have chosen me for a subject this evening, and with a few preliminary remarks I will reciprocate by taking as my text Uncle Joe Butler.

While sitting here expecting possibly to say something, and feeling rather unhappy about it, I was reminded of what Mr. Depew, whom Mr. Butler spoke of, once said to a lady with whom he was examining some pictures. One of the pictures showed Daniel in the lion's den. She said, "Mr. Depew, I don't understand why Daniel should be painted with such a contented and happy countenance." "Well," he said, "he knew there would be no speech after the banquet." (Laughter.)

I must take this opportunity of joining with Mr. King and Mr. Butler and the other speakers in congratulating our president, Judge Gary, upon the best speech upon that subject or a kindred subject that I have ever heard; not only the best speech, but the most timely speech—a speech that will reflect the opinions of the people throughout this great country, at a time when such impression is so important and necessary. I have heard nothing but the most favorable comments in every direction. (Applause.)

Now, the Judge asked us to criticise his speech. I am going to take him at his word. When I prepared the data for that paper for the Judge (laughter) especially that part referring to the increase of our navy, it was distinctly understood that the Judge was to say that the Bethlehem Steel Company is peculiarly well qualified to

do that kind of work. Now, he did not make that statement; so in that respect, and in that respect alone, do I criticise his admirable speech.

Like the preacher, I have now come to the main subject of my discourse, and I think I cannot do better than read a letter I received this evening just before I came to this meeting. You know the Judge was very optimistic and very hopeful in the closing remarks of his address today, and I sat thinking of the story of our first meeting, and why we should be so hopeful with so many things going on in business. And then I read Uncle Joe's interview in the paper this morning, in which he said that we are going to have the pleasure of ladies in the steel works in the years to come. I suppose most of you read that interview. I know someone in Mahonoy City read it, because this is what he wrote to me:

My dear Mr. Schwab: I seen in the paper this morning that Joseph G. Butler, Jr., says women will be working in the steel mills soon. I write to find out if you could get my old woman on the job. If you could put her to work some place in the explosive factory I would appreciate the favor very much. Wages is no consequence, and I will not ask for damages in case of accidents. (Laughter.) I don't know who this man Butler is. I bought a mining stock with that name once and I still have it for reasons of my own. Can you tell me whether or not this Mr. Butler is suffragetically inclined, as I myself am in favor of women working. I would like if you could put my old woman on the night shift. I hope you will do this favor. I once worked for the Carnegie Company when you was there, and all the boys say if you done all the things you say you had done that you wouldn't be where you are today. If you aint in a position to help me, I would consider it a favor if you asked Mr. Butler to help me. I never heard of Youngstown, the place where he says he lives, but maybe the newspapers mispelled the name. (Laughter.) Thanking you in advance for getting my old woman a job in that explosive factory, I am, Yours truly, Jacob A. Schwarzheimer. (Laughter.)

Before I sit down I want to add just a word or two of seriousness. Judge Gary has been talking for many years about co-operation. He hasn't said much about it today. I think it is about time that some of the rest of us take a serious view of this co-operation principle. We must not be like the Irishman on the boat who was learning to heave the lead before letting the anchor go. The man aft was singing out, "Eight fathoms," and so on, and all of this talk was as Greek to the Irishman. He did not understand, but, not to be outdone, he uttered some unintelligible words, and so the captain called out to him, "What are you shouting? I don't understand what you say." The Irishman replied, "Well, captain, I have learnt the tune but I haven't learned the words yet." (Laughter.) And so it is with us. We have learned this tune of co-operation, but we haven't learned the words, that is, how to put it into practical operation.

Now, we have come to a time in our business, the greatest business in the United States—except cement, and it occurred to me while Mr. Hagar was telling about the wonderful things that they had done to develop cement and we had not done to develop steel, that perhaps they needed it. (Laughter.) But let us co-operate; let us do so in fact. That storm of adverse sentiment that swept over the country for years has vented itself, has expired of itself, and we will not feel in the future the unjust attacks that we have had to bear. The President of the United States has plainly and openly stated that we ought to co-operate, and he has promised that our laws are to be changed. The world at large has come to realize that business is for profit, and development cannot be done in any other way successfully, that we ought to co-operate much more closely than we have, and that we, the minor people in the industry, ought, in view of what Judge Gary and his associates have done in the past, to take the leading steps for that co-operation in the future. With the years of prosperity that loom ahead of us, with the years of great product that are to come, it seems to me that

that is the time for us to reap the benefit of these things.

There are some men who acquire riches, some who are born to riches, and some who have riches thrust upon them. And so it is with the steel business: there are some that want orders, there are some that are getting orders, and there are some that have orders thrust upon them. (Laughter.) In the years to come we will all have orders thrust upon us. I believe that we are at the beginning of a prosperous era. I do not want to make too many predictions, because one day when passing through the mill, I heard one man say to another, "It is wonderful how accurately Mr. Schwab predicted that," and the other man answer, "Well, he ought to hit it sometimes, because he makes so many predictions." But I do believe that this is a time, after these three or four years of bad times, when we are going to see good business, and let the business be good in volume, let it be good in co-operation, let it be good in sentiment, and let it be good in the fellowship that exists in the wonderful organization, that the previous speakers have so eloquently described, a fellowship which is destined to grow greater and more influential and to bring us closer together in the bonds of friendship and business success. (Applause.)

President Gary: You have been expecting to hear from another gentleman, and it is now my pleasure to introduce him, Mr. James H. Hoyt. (Applause.)

Mr. Hoyt: Mr. President, Ladies and Gentlemen: Dr. Noland very kindly suggested that we should furnish ourselves with proper baths. That reminds me of the story of an English gentleman who was very much impressed with the bathing facilities with which good American houses are ordinarily equipped, and when he went back home he installed in his country place a very fine roomy, porcelain bathtub, and all the necessary accessories and fittings. Shortly afterwards an American gentleman

visited the Englishman. After taking the American to his home, the Englishman said, "You know, I have a surprise for you. You will not now have to bathe in the tin tub. I have installed a bathroom of the American kind, porcelain, tub, shower, and all that, hot and cold water and stopper and everything that goes with it. It is right next to your room, and I hope you will avail yourself of it." The next morning when the American came down the Englishman said, "Well, I suppose that you have availed yourself of the bathing facilities and the hot and cold water and the shower and the rest of it?" "No," said the American, "I didn't. I bathed this morning in the tin tub that your man brought to my bedside." "God bless my soul, I go to all this expense and trouble, and then you do not avail yourself of it," said the Englishman. The American said, "I went to the bathroom this morning, but when I opened the door I found your wife in the bathtub." The Englishman said, "No, did you? God bless my soul, she's a skinny old thing, isn't she?" (Laughter.)

Another story that Dr. Noland reminded me of was that of a New York lady who was extremely extravagant and spent much money on millinery and dressmaking establishments. Her husband finally said that he would decline to pay the bills, and if necessary he would advertise publicly that he would not be responsible for her extravagance. So the next month there were no bills from the millinery and dressmaking places, but a large bill came in from Fleischmann's turkish bath. He looked at the bill and said to his wife, "How is this?" and she said, "Where else can a lady go who has nothing to wear?" (Laughter.)

I did not have opportunity to listen to that very sterling address of our President this morning, but I had the pleasure of reading it yesterday as our Secretary was good enough to send me advance sheets. It was an admirable, splendid address. I agree with our President absolutely, that the clouds are breaking away and that

good business, intelligent business and honest business will now be favored and not be jeered at or too much restricted. The time of the demagague and the man who speaks on the head of a barrel is passing away, and there are two very prominent citizens of the United States who, in my judgment, are as much responsible for this condition as any other men. One is the President of this institution. (Applause.) He has aided not only by what he has said, but by what he has so constantly done. His sanity, his fairness, his magnanimity, his spirit of conciliation, his organized attempt to co-operate in all great business enterprises has been a beacon light to show the people how important it is to understand that the country cannot be prosperous unless capital is well invested and is fair. The old adage that silence is golden and speech is silver is sometimes reversed. Of course, there are times when argument is as hopeless as an argument with a jellyfish. An argument with the people of the United States when the whirlwind of passion arouses them to a fit of hysteria is also useless, and anybody who attempts to argue at a time like that is a good deal like the little dog who saw the cyclone coming and barked at it and was blown inside out. But there is a time when it is well to reverse that old adage, when silence no longer is golden, but speech is golden and the time has arrived now, as Judge Gary says.

The other gentleman who is largely responsible, in my judgment, is the best ex-President we ever had in this country since the time of George Washington. I refer to Judge Taft. (Applause.) He told me a story the other day which illustrated a change of mind—how people who had been hostile at one time had come to the conclusion that they made a mistake. He said that when he was a member of the Cabinet of Mr. Roosevelt, a letter was received one day dated Laramie Prison, written by one of the Rough Riders of the Colonel, in which the writer said, "I am in awful trouble again, and this time they done me wrong. They got me in jail for shooting a

lady in the eye. God knows I wasn't shooting at her at all. I was aiming at my wife." (Laughter.)

If you will bear with me a moment, I would like to say something on a phase of another subject. We are not like the Irishman who rushed into a saloon, and finding a fight going on between two individuals, threw his hat on the floor, and said, "Is this a private fight or can any one go into it?" We do not want to get into a fight, but for a reason which has been stated by the greatest man in the world, George Washington, we want to be prepared. The more I read of George Washington's biography the more I am impressed with his greatness and with his sanity, and in his first inaugural message this is what he says—and in the present juncture it is a thing that every American ought to remember. He said to the Congress: "The respect of the nations of the world for the United States government will be withheld if not absolutely lost if we permit a reputation for weakness to prevail. If we desire to avoid invasion, we must be ready to repel it. If we wish to secure to ourselves lessons of peace so essential to us in our rising prosperity, we must be prepared for war." That sentiment was uttered more than a century ago, but it is just exactly as true today as it was then. I have no use for an army or navy for aggression: I have every use for an army and a navy for defense. Gentlemen, our army and navy are both in a lamentable condition. The glowing expectations of the Secretary of the Navy so publicly, eloquently perhaps, expressed on the seventh of this month have now been taken back. Lieutenant-Commander Sterling was right and the Secretary of the Navy was wrong with reference to the conditions existing with regard to our submarines. Our army, what is it? Why, the officers of the German army were in number—or were before this war began—more than twice the entire available regular army and fighting trained force of the United States. Now, we are fortunately very well placed, but while we are not anxious to bombard the cities of any other nation now—

I emphasize the now because that desire was not so apparent when we sent an army and a fleet to Vera Cruz because of their failure to salute the flag, and then withdrawing apparently forgetting the real object of our going there—but now we do not wish to bombard the cities of any other nation. But if any other nation proposes to bombard us we should be prepared, and we ought to have an army, not too large an army, but an army large enough to defend the United States in case of attack. We do not propose to attack anybody else, but we ought to be prepared for defense against attack.

I agree with the President on that, and I agree with one other statement that was made, that in time everything would right itself, and that the prospects were bright. In closing let me quote from William Cullen Bryant, who said:

> Truth crushed to earth shall rise again,

and I think, ladies and gentlemen, that the time has arrived in this country when attacks on great business, honest business, intelligent business and progressive business has been found by the people of the United States to be an error, and that error, has, I trust, at any rate for the present, received its body blow.

President Gary: Gentlemen, we have kept our promise. Our program is finished. I thank you for your presence during the day. Especially do I thank the young men who have prepared and read such splendid papers on technical subjects. I am very grateful for the kind words which have been said concerning your President. They are undeserved, but they show a feeling of friendship which is more valuable and more appreciated than anything else that could be rendered. I bid you good night.

OCTOBER MEETING

CLEVELAND, OHIO

October 22 and 23, 1915

Some of the Members and Guests that Assembled at the Banquet, Cleveland Meeting

AMERICAN IRON AND STEEL INSTITUTE

NINTH GENERAL MEETING

CLEVELAND, OHIO, OCTOBER 22 AND 23, 1915

The Ninth General Meeting of the American Iron and Steel Institute was held at Cleveland, Ohio, on Friday and Saturday, October 22d and 23d. The attendance was larger than at any previous meeting, numbering over five hundred members. In addition there were over one hundred guests of members at the day sessions and the banquet.

The sessions were all held in the Grand Ball Room of the Statler Hotel, which was found well adapted for such a meeting. The papers measured up to the high standard set by previous meetings. On the next page will be found the program of papers.

Saturday was devoted to seeing Cleveland. The Local Committee, of which Mr. Samuel Mather was chairman and Mr. John A. Penton, secretary, had mapped out a very interesting day. It began with a visit to the plant of the White Automobile Company, which was followed by a visit to the dock of the Ohio and Western Pennsylvania Dock Company, where the members had the opportunity of witnessing the unloading of iron ore from the *J. Pierpont Morgan.* Four Hulett solid arm unloaders and one Hulett storage bridge were seen in operation. Each unloader has a pocket capacity of 17 tons and the entire plant has a capacity of 3,000 tons per hour in unloading a modern vessel in its entirety. On July 2, 1915, this plant unloaded the steamer *James A. Farrell,* taking out 11,183 tons of iron ore in 3 hours and 35 minutes, the vessel being tied to the dock only 3 hours and 40 minutes.

The members were guests of the Cleveland Country Club for luncheon, after which those who felt so disposed had the freedom of the club grounds for playing golf. It is the verdict of those who attended the meeting that Cleveland lived up to her high reputation for hospitality.

FORENOON SESSION, 10:00 A. M.

Address by the President..ELBERT H. GARY

Cleveland and Its Industries..SAMUEL MATHER
Pickands, Mather & Company, Cleveland, Ohio.

Modern Methods of Burning Blast Furnace Gas in Stoves and Boilers..AMBROSE N. DIEHL
Assistant General Superintendent, Carnegie Steel Company, Duquesne, Pa.

Discussion..HENRY P. HOWLAND
Superintendent of Blast Furnaces, Wisconsin Steel Company, South Chicago, Ill.

Discussion..ANDREW E. MACCOUN
Superintendent, Edgar Thomson Blast Furnaces, Carnegie Steel Company, Braddock, Pa.

Discussion..WILLIS L. KING
Vice-President, Jones & Laughlin Steel Company, Pittsburgh, Pa.

Heat-Treatment of Steel in Automatic Electric Furnaces..THADDEUS F. BAILY
President, The Electric Furnace Company of America, Alliance, Ohio.

Discussion..SAMUEL T. WELLMAN
Chairman, Wellman-Seaver-Morgan Company, Cleveland, Ohio.

Discussion..JOSEPH W. RICHARDS
Professor of Metallurgy, Lehigh University, South Bethlehem, Pa.

AFTERNOON SESSION, 2:00 P. M.

General Principles of the Control of Piping and Segregation in Steel Ingots..HENRY M. HOWE
Professor of Metallurgy, Columbia University, New York City.

Discussion..EDWARD F. KENNEY
Metallurgical Engineer, Cambria Steel Company, Johnstown, Pa.

The Mechanical Development of Sintering of Iron-Bearing Materials..BETHUNE G. KLUGH
Chemical and Metallurgical Engineer, American Ore Reclamation Company, New York City.

Discussion..ROBERT E. BROOKE
Treasurer, E. & G. Brooke Iron Company, Birdsboro, Pa.

Discussion..HERMANN A. BRASSERT
Superintendent, Blast Furnaces, Illinois Steel Company, South Chicago, Ill.

Under-Advertising of the Steel Business..GEORGE H. JONES
Vice-President, Inland Steel Company, Chicago, Ill.

Discussion..HUGH KENNEDY
Vice-President and General Manager, Rogers-Brown Iron Company, Buffalo, N. Y.

Development, Manufacture and Uses of Alloy Steels for Commercial Purposes..EDGAR D. ROGERS
General Sales Manager, United Steel Company, Canton, Ohio.

Discussion..GEORGE L. NORRIS
Engineer of Tests, American Vanadium Company, Pittsburgh, Pa.

EVENING SESSION, 7:00 P. M.

DINNER

Moving Pictures of Processes..H. E. HORTON and F. N. SPELLER
American Steel & Wire Company and National Tube Company.

Impromptu Remarks in Response to Call of the President

Closing Remarks by the President..ELBERT H. GARY

ADDRESS OF THE PRESIDENT

Elbert H. Gary
Chairman, United States Steel Corporation, New York

PUBLICITY

"The public be damned."

Many years since it was openly charged that this expression was used by a business man of great prominence. There has been a prevalent belief that the charge was based on fact and it has caused a feeling of prejudice which has been exceedingly harmful to the business interests of the country.

It is doubtful if the statement was ever made by any one of great importance, particularly by the gentleman to whom the same was attributed. Whatever the truth may be in regard to this well-advertised and much-discussed expression, it is no doubt true that the sentiment which it conveys has in days gone by existed in the minds and actuated the conduct of a considerable number of the leading business men of this country and other countries during various periods of their history. Included in this class are men of intelligence and influence in all the various departments of industrial activity.

Within a few years, comparatively speaking, we have listened to the arguments of distinguished business men who insisted that if they violated no rule of law, if they withheld from the public nothing which the law positively and affirmatively compelled them to disclose, they were without fault, even though a large portion of the public might be adversely affected by a failure to reveal information which might be received in an official or fiduciary capacity or as the result of circumstances which gave to an individual a decided advantage over others. Most of

us know of cases where officers of corporations have acquired wealth by acting for themselves to the prejudice of others who were interested and were not in a position to protect themselves because of the lack of publicity. Some have dealt, to their great advantage, in the markets of the world upon advance knowledge of what might be expected as the outcome of conditions or facts not generally known at the time and before the facts were communicated even to the other stockholders. They violated no rule of law and, probably, in their opinions, no rule of moral conduct. This is a charitable view to take.

It has in the past been considered by men of probity and high standing that private corporations, so called, as distinguished from public or quasi-public corporations, were literally private and that the public had no greater right, legal or moral, to inquire into the affairs of the corporation than it had to question the personal matters of the individual or family. Sometimes the management of corporations, including the boards of directors, have withheld from the general public facts which directly affected the public interests, and even though no rule of law was violated, yet widespread harm was done. In many cases men of prominence and influence have been totally indifferent and defiant when considering the public welfare.

It is needless to say that, because of this attitude on the part of some of the business men, the whole fraternity has been seriously affected and has suffered unjustly. For a period of years big business, so called, the good with the bad, was antagonized to an extent which materially interrupted its normal and legitimate progress; and it is believed this was occasioned in part by the suspicion created from the failure to take the public into the confidence of private enterprise so far as practicable and proper.

The general public and private individuals have been in the past too far apart for the good of both. Lack of knowledge often breeds unnecessary and hurtful an-

tagonisms, and many have suffered even though they were not personally at fault.

Principles of Proper Publicity.

These casual remarks are preliminary to a brief discussion of the topic of publicity which is one of the most important questions of the day. Much has been said and written upon the subject during the last few years, and apparently there have been contrary opinions. It is believed, however, that there is really not much difference in the minds of intelligent and fair-minded men as to what is desired, although in the consideration of any important question there will be found those of extreme views who, on one side or the other, will insist upon that which is unreasonable. If the public is approached in a fair spirit it will generally reciprocate. (Applause.)

There are from time to time many facts in private business, some of great importance, which cannot properly be made public and ought not to be insisted upon. All who are present know by actual experience, and every other intelligent person will recognize the fact, that in current business affairs where competition is essential, there are always a great variety of questions which must be treated as private and withheld from publication in order to stimulate business and accomplish success. This is and will always be the rule, though there may be exceptions in order to meet the exigencies of special conditions. If a man in business should open every detail to the inspection of all others he might seriously interfere with his own progress and benefit no one, except such as might be disposed to profit unfairly at his expense; while, if he declined to disclose these private matters, nobody would be injured. Neither the public nor any one except the individual person or corporation involved is entitled, on any ground, to possess the kind of information now under discussion. It is not necessary to specify the facts pertaining to individual affairs which are strictly private; any man may apply the

principle to his own matters. Perhaps it is impracticable to draw a definite line between the facts which should be given to the public and those which may be considered private; and quite probably there should be an impartial public tribunal to determine; but this is another question. "The public" as used might comprise large or small numbers.

It is not practicable to determine a standard for publicity which is exact and applicable to all cases. Circumstances and conditions must be considered; but a general rule may be stated thus: There should be published whatever of business matters the public is legally entitled to know and also whatever may affect the public interest and may be exposed without detriment to the corporation or individual concerned.

Proper Legislation Regarding Publicity.

Legislation or administration of laws or any practice of governmental agencies that seeks to go further than this rule is vicious and should be condemned. I believe thoroughly in publicity, so far as it is practicable and proper. We should not be like owls. It should go without saying that the officials of a corporation ought to keep the stockholders promptly and fully informed, so far as possible, without damage to its current business. They have no moral right to profit individually to the detriment of other stockholders as the result of information officially obtained. (Applause.)

However, during the present decade there has been a pronounced change in the attitude of large business interests concerning the disclosure of facts and figures to the general public. Many now, voluntarily and without the requirement of law, make regular and complete reports so that any one interested may know the results of the business and the general policy of the company; and whenever requested by representatives of the press they furnish facts in corroboration or denial of rumors which are considered important when the information can be given

without prejudice to the business and appears to be of concern to the public. Probably it will not now be denied that the average business man is quite disposed to be accommodating in this respect.

Wisdom of Reasonable Publicity of Business Affairs.

And what follows? It will not be questioned that the great business interests of the country have been benefited by this change in disposition toward the public which has become less distrustful of capital and its controlling influences. It has been more considerate of the rights and claims of those engaged in great enterprises and less inclined to listen to the plea of the demagogue. Indeed, it has patiently and fairly heard and read all that has been said in favor of granting relief to any concern that sought assistance on a fair and reasonable basis; and not infrequently, because of a public sentiment that the request was just it has been granted. Included among those who have seemed to change their opinion toward the business interests are multitudes of wage earners, of business men of small means, of educators, lecturers and editors, of the leading thinkers, writers and public speakers of the country. There is abundant evidence that at present the great general public is willing to meet half way the individual or the corporation in the determination of all questions that affect private or public interests.

Is it too much to urge that from every standpoint it pays the business man or any man possessed of information which affects the public weal, to disclose the same so far as practicable and reasonable? Is it too much to insist that publicity is the cure for many of the ills from which the country has been suffering in the past? Publicity has never done as much harm as secrecy. The individual or the corporation with a disposition to publish whatever facts were proper to be known has, without many exceptions, been treated justly; while those who have been defiant, arrogant and secretive have suffered. So far as I can see, the great business men of this country are, at the

present time, in close contact with the public. They are striving to work together for the good of all. We shall see great and favorable results. (Applause.)

Proper Publicity on Part of Public Officials.

These observations relating to private men and enterprises apply with equal force to public officials, to municipalities, states and governments. The public is entitled to know what public officials are doing and what policies are being considered or enforced, though, of course, it may, and often does happen, in individual cases, that information cannot be generally given out without injury to the cause involved; and in such cases the responsible official must withhold publicity temporarily, and, possibly, in some cases, permanently. It is fair to say, public officials have often been as indifferent to the rights and interests of the general public as private officials or persons have been. It would be better for all concerned if the officials of municipalities and even states and countries were more inclined than they have generally been to confide the knowledge in their possession to the people at large.

Proper Publicity Would Have Prevented Present War.

This idea has peculiar application to the present situation in Europe. If the masses of the people of the different nations engaged in the terrible conflicts that are now waging in Europe were fully informed of all the facts, is it to be supposed the wars would be much longer continued? If they and every one of them, in the armies or at home, knew, as now published in our newspapers, that the daily cost of the war is eighty-five million dollars, or at the rate of thirty billions per year, an annual interest burden, at five per cent., of one billion five hundred million dollars, and that the indirect loss is about as much more; if they were aware that, on the basis of the war being prolonged to next February, there will have been killed in battle at least five million men, deaths from sickness two million, five hundred thousand, and permanently crippled

five million more—and these the very best; if they could see that seventy-five per cent. of the men in the armies who survive will never fully recover, physically or morally, from the effects of their service and association; if they realized that their countries are drifting, nay, speeding, into bankruptcy and must necessarily hereafter and for many years be at a decided disadvantage in the race with other nations for progress and success; if they understood that on the present basis of pension payments in the United States the amount to be paid for this purpose in consequence of the war will approximate one billion dollars per year; if the leaders, the monarchs, the few who plan and control and command and know in advance and in detail what has been and is being done and is intended for the future, were to communicate all the facts to the public, when it could be done without prejudice to the daily conduct of the war; if all these startling facts and figures were of universal knowledge, would not the people, including the soldiers in the ranks, rise up in such vigorous protest against a continuance of the conflict as to compel the men in control to find some way of bringing it to a satisfactory termination and for the establishment of a basis which would prevent future, prolonged wars? If, indeed, before the wars were started the masses of the people of the different countries had been informed that wars were to be started, and the reasons or lack of reasons for starting them, would they have submitted to their precipitation?

It is not too much to demand that the people should know the reasons for the commencement and the continuance of the pending wars and they should understand the awful consequences. Those who are directly affected and must bear the burdens are, in a large measure, ignorant of the facts which have been suppressed, partly at least, because knowledge of those facts would prevent a continuance of the most stupendous, if not the most unreasonable, destruction of life and property the world has ever witnessed.

I leave this subject by proposing as a substitute for the quotation referred to at the beginning of these remarks the following from the Bible (Romans XIV: 7):

"For none of us liveth to himself, and no man dieth to himself."

Present Business Conditions.

The business men of this country, particularly those engaged in the iron and steel trade, have reason to be thankful for the present conditions, which are very prosperous. The furnaces and mills are generally operating to full capacity and prices received for many, if not most, of the commodities produced are larger than they have been during the last few years and should result in profits.

We are at peace with all the world and it seems likely that the wise policy which has permitted this state of affairs will be continued. We sincerely hope and pray that the wars which are raging in Europe may soon be brought to a close and a basis reached for the prevention of prolonged wars in the future.

Apparently we are to have a period of industrial peace in this country. Many of the antagonisms, which have hitherto been so hurtful and which have prevented natural business growth, have disappeared and legitimate business will, therefore, have opportunity to progress in accordance with its deserts.

No doubt the sudden and marked improvement in conditions during the last six months is due, in a large measure, directly or indirectly, to the purchasing necessities growing out of the wars; but there are other reasons.

The Future of the United States.

The total wealth of the United States, according to the last published figures, is more than one-fourth of the aggregate of all the nations and it is rapidly increasing. Many of us believe that we may become and remain the leading nation, financially, commercially and industrially, provided nothing unnecessary is done by our people to prevent. Personally, I do not agree with the statements

which have been made that, at the close of the wars, we may expect in this country a prolonged continuance of the great prosperity now experienced; especially if we do not have protection against the results of cheap labor and the impoverished conditions abroad, which are inevitable. I do think that, with wise administration and with the co-operation of the state and national governments, our industries will be able to recover from the injurious effects of the wars much more rapidly than those of any other country, and that within a few years we shall be more successful than ever before.

The value of good crops we all understand and appreciate. Evidently the seasons' crops are, in most respects, excellent and with a good market therefor the farming communities will be prosperous and the country at large will be benefited.

The American Iron and Steel Institute is to be congratulated on the good work it is doing and the high reputation which it deserves and has secured and particularly on the splendid services which are being rendered by the young men, including those who are producing at our meetings, for our benefit, most admirable discussions of various topics which directly affect our industry. (Applause.)

President Gary: Is there any discussion of the President's address? (After a pause.) The Secretary has some announcements to make.

Secretary McCleary: Big cities, like big men, are proverbially generous when they know the facts. Cleveland is a big city. It knows the Institute. It wishes the members of the Institute to feel at home here. The Cleveland Committee has spent a great deal of time preparing for this meeting. Among other things it has arranged that at the various clubs, the members of this Institute shall be members *pro tem* without any bills coming in later. If you wear your button, or, in the absence of the button, take your card showing that you are going to be at the banquet, either is an open sesame. You can

order whatever you want, sign a check, and forget it. (Applause.) If you find a gentleman with one of these blue ribbons in addition to his official button, you may understand thereby that he is one of Cleveland's entertainment committee. Just ask him for anything you desire. In case you forget what I am now telling you, you will find it all in this program, a copy of which you can get at the desk of the Secretary in the registration room.

A number of the members are in the habit of bringing their wives with them to these meetings. Cleveland wishes these ladies to feel at home, and has made arrangements to that end. A luncheon for the ladies has been provided at the Union Club, across the street from this hotel. For the gentlemen a luncheon at the Country Club has been provided. Both luncheons today, at one o'clock. (Applause.)

President Gary: We shall now have the pleasure of hearing something about "Cleveland and Its Industries," by Mr. Samuel Mather.

CLEVELAND AND ITS INDUSTRIES

Samuel Mather
Pickands, Mather and Company, Cleveland, Ohio

Those of your membership resident here in Cleveland are delighted to extend to you a most cordial and hearty welcome. We are very much pleased that you elected to have your October meeting here; and, while no public reception by the Mayor, or the Chamber of Commerce, or the citizens of Cleveland generally, has been arranged for, yet I assure you it is not because they fail to appreciate the honor of your coming, but simply because the resident members knew from past experience that your time would be entirely taken up in the transaction of your own business, and in the sight-seeing trips that have been planned for tomorrow.

"The Western Reserve."

The subject that has been given me for my short address is, "Cleveland and Its Industries." Like most American cities west of the Alleghenies, Cleveland has no long history to look back upon; she is still in the heyday of youth. At the conclusion of peace with Great Britain, after the Revolutionary War, the vast area lying beyond the Allegheny Mountains and bordered on the west by the Mississippi River, belonged generally, of course, to the thirteen states. There were many claimants to this vast tract of land, but by 1785 all of these claims were amicably settled, excepting those of Connecticut; but after considerable controversy, Congress settled with Connecticut also, by deeding to her the land between the forty-first and forty-second degrees and two minutes north latitude, for a distance of 120 miles west of the western line of Pennsylvania. This tract

of land was the famous "Connecticut Western Reserve," which became within a quarter of a century after its creation the home of a transplanted New England. Part of this tract, at the extreme westerly end of the Reserve, was donated to those citizens of Connecticut who had suffered by the burning of their homes by the British during the Revolution. The balance was sold, in 1795, to some thirty-five or six citizens of the state for the sum of $1,200,000. These purchasers pooled their interests and formed the Connecticut Land Company. The following year—1796—they sent out a surveying party under the command of General Moses Cleaveland, of Canterbury, Connecticut, which party arrived at the mouth of the Cuyahoga River on July 22, 1796, and on the 16th of September of the same year began their survey of the land where the city of Cleveland now stands.

"Cleveland, the Sixth City."

While, no doubt, it would be overlooked by you, yet I feel I should hardly be pardoned by my fellow-citizens, who may be present, if I delayed longer to make mention of the fact that Cleveland is at present the sixth city of the United States in population, which was estimated by the United States Census Bureau here, on July 1, 1914, at 639,431; and the fifth city of the United States in the value of manufactured products, according to the United States census of 1910. It was in 1820 that the village of Cleveland was incorporated, with a population of 606 inhabitants; and it was in 1832 that the canal from Cleveland to Portsmouth on the Ohio River—a distance of 309 miles—was completed, which gave Cleveland its first impetus of growth through the facilities of communication with the other portions of the state thus obtained.

In 1834 the Cuyahoga Steam Furnace Company was incorporated under the first state charter issued to a Cleveland manufacturing concern, and it was the first iron industry in Cleveland or vicinity to use steam instead of horse-power for "blowing" its forges and furnaces.

In 1841 this company made cannon for the United States Government, and at this plant was built the first locomotives used by the Cleveland, Chicago and Cincinnati Railway; and there also the machinery for the first successful lake screw propeller, called the "Emigrant," was built.

Ship-Building on the Great Lakes.

Ship-building on the Lakes received its first impetus from the War of 1812, when ship carpenters were brought to the Lakes to build the stanch fleets that added so much to the glory of American valor. From this early beginning, ship building in Cleveland and the neighboring harbors progressed, slowly at first, until after the opening of the Sault Ste. Marie Canal, and then more rapidly, until in 1882 the first iron freight steamship intended for the carrying of ore and grain, was built in Cleveland by the Globe Iron Works, and called the "Onoko." At the present time Cleveland is the headquarters of The American Ship Building Company, and at their works here and at neighboring Lorain, Cleveland outranks all other American cities in the production of steel ships.

It was undoubtedly owing, however, to the discovery of copper and, more particularly, iron ore in the Upper Peninsula of Michigan, which latter was first discovered on September 19, 1844, at the Jackson Mine, Negaunee, and to the opening of the Sault Ste. Marie ship canal, in 1855, that contributed most to the great growth of Cleveland, for this city then became the natural meeting-place of the bituminous coal from the coal fields of Southern Ohio, Pennsylvania and West Virginia, and the iron ore from the Lake Superior district. The Jackson Iron Company shipped the first ore, in six barrels, in 1852, but The Cleveland Iron Mining Company, in September of the following year, shipped the first cargo of ore, amounting to 152 tons, to The Sharon Iron Company, at Sharon, Pennsylvania. This, of course, was before the completion of the Sault Ste. Marie Canal, and it was portaged over the falls. From this small begin-

ning has sprung this vast industry, so familiar to all of you, until in 1913 the shipments amounted to between 49,000,000 and 50,000,000 tons, and the size of the boats have increased from 152 tons to boats of the class that you will have opportunity to inspect unloading tomorrow, with a capacity of 13,000 tons.

Beginning of the Steel Industry.

Between 1850 and 1860, Henry Chisholm and the two Otises, William A. and Charles A., started their iron and steel works—that organized by Mr. Chisholm becoming The Cleveland Rolling Mill Company and today being a part of The American Steel & Wire Company, and that organized by the Otises having become The Otis Iron & Steel Company. I am advised that the first Bessemer steel blown at Mr. Chisholm's plant, in Newburgh, on October 15, 1868, was prior to the making of Bessemer steel in Pittsburg by several years. I might mention many other names, well known in Cleveland, who were also pioneers in the iron and steel industry in this city, but my time does not allow me to go into this matter further.

Beginnings of the Petroleum Industry.

It was in 1860 that we find the first suggestion of the petroleum industry, novel at that time, of which Cleveland was the cradle, and with whose astonishing history the name of this city is inseparably associated. In 1861, Mr. John D. Rockefeller and Henry M. Flagler formed their partnership, and in 1870 expanded into The Standard Oil Company, with Cleveland as its headquarters. For a long time it was one of the leading, if not the leading, industries of Cleveland; but today the oil industry ranks sixth in the total value of its products—the iron and steel industry coming first with a total value of manufactured products, according to the 1910 census, of $76,000,000, employing over 28,000 men. Next in rank to iron and steel comes the automobile industry, which,

against nothing reported in 1900, showed a value of products in 1910 of $21,400,000. Today Cleveland stands second in the United States in this new and vast industry.

Slaughtering and meat packing is the third industry in importance in Cleveland, and the fourth in order is the manufacture of women's clothing. Berlin and New York only are larger producers of women's outer garments than Cleveland, which has three of the four largest producers of these artistic garments in the world. My immediate auditors may not be particularly or keenly interested in this fact, but I suggest that you store it away in your memory and tell your wives and daughters; and I should like to add this fact, that, in the excellence of buildings and equipment in this industry, Cleveland leads the world.

Very near Cleveland are situated also the Berea and Amherst sandstone quarries, which, I am told, are the largest quarries of that character of building stone in the world.

There are more than 42 extensive lumber yards in this city, over two-thirds of which are along the Cuyahoga River, where admirable facilities exist for unloading shiploads of lumber; and by far the greater portion of this lumber is worked up in the building trade industry, and the manufacture of furniture, window sashes, automobile bodies, sewing machine cabinets, etc.

"The City of Varied Industries."

The industries of Cleveland, in fact, produce such a large number of different articles that, in the commercial world, it has become known as the "city of varied industries." I shall not take the time for going too minutely into these; the most of you, yourselves, know quite as much, if not more, about the iron and steel industry in Cleveland than I do myself.

You know there are ten blast furnaces here with an average output of 120,000 tons monthly; that, because of its vast output of nails, spikes, screws, tacks, drills and

bolts, Cleveland has been called "The Sheffield of America"; that many kinds of steam hammers, lathes, punches, rolls, drills, shears and forges are built here; that there are large manufactures of copper, tin and sheet iron, and of brass and bronze; that it outranks all other American cities in the production of wire and wire nails, electric carbons, bolts and nuts, dry batteries, sewing machines, malleable castings, heavy machinery, and many other articles. In a word, the statistics of 1910 show that Cleveland produces considerably more than 2,000 different kinds of manufactured articles, in 2,148 establishments, engaging approximately 100,000 wage workers, with the manufactured products valued at $272,000,000.

It is impossible to go, in the short space of time allotted me, more minutely into details; but I cannot avoid calling to your attention the fact that the great Lick and Yerkes telescopes were made in Cleveland; that the largest manufacturer of paint in the world is The Sherwin-Williams Company, of Cleveland; and that the pioneer manufacturer of unloading machinery is situated in Cleveland—The Brown Hoisting Machinery Company. The Hulett ship unloader is also manufactured here.

Land and Water Transportation.

Seven trunk lines of railroad, many lines of passenger boats, besides freight boats, five electric lines and 130 miles of paved roads leading into the city, constitute our main traffic advantages, to which should be added The Cleveland Short Line Railway, a belt line recently completed at a cost of $18,000,000, which makes a circuit of 19 miles around Cleveland, intersecting every railroad entering the city at a point near their yards, without crossing any street railroad lines or thoroughfares at grade. It is said that this is the shortest and most convenient belt line in any American city, with the easiest grades.

The development of Cleveland's outer and inner harbor has also received especial attention—about $6,000,000 having been expended by the United States Government, chiefly in the construction of the breakwater protecting the outer harbor. The city of Cleveland has expended upwards of $3,500,000 in the improvement and maintenance of the Cuyahoga River, which is now navigable for boats drawing 20 feet of water, for a distance of about four and one-half miles. $1,000,000 more has been voted for immediate further improvement of river navigation. The total tonnage of all freight received by lake in 1914 was 9,900,000 tons, and the shipments amounted to 9,300,000 tons. The freight received by rail amounted to 20,300,000 tons, and the shipments by rail were 12,000,000 tons. This includes shipments of about 4,000,000 tons of bituminous coal.

An ordinance to be voted upon by the electors on November 2d, will, if passed, give the city the ownership of the lake front opposite the center of the city, for a further distance of approximately a mile; and, if this ordinance is approved, undoubtedly great improvement in the outer dock facilities may be looked for.

Banking facilities are, of course, an important factor in the development of any community, and the establishment of the Federal Reserve Bank of the Fourth District at Cleveland is a recognition, in part at least, of Cleveland's sound banking record, and of its industrial and commercial development. The deposits in Cleveland banks on June 15th were $335,000,000, more than one-third the total deposits in all the banks of the State of Ohio.

Cleveland a City of Homes.

Cleveland has a temperate climate, and has the lowest death rate of any of the ten largest cities of America. It has a new charter, adopted in 1913, which provides for a government based on the federal plan, concentrating authority in the chief executive, the mayor. The increase

in population from 1900 to 1910 was 47%. It is estimated that 25% of the population are born of native parents; 10% have one foreign parent; 30%, while native born, have foreign parents, while the remaining 35% are foreign born.

Cleveland also has been in a happy condition in regard to its labor market, having an excellent supply of high grade labor at all times. It is a city of workingmen's homes. The British Board of Trade, in reporting on working-class rents, housing, etc., in the United States, commented very favorably on the workingmen's homes in Cleveland. The census of 1910 showed that over 35% of Cleveland homes were owned by their occupiers.

Like most American cities, Cleveland has excellent public schools for the education of its children, including commercial and industrial high schools; with excellent private schools; and for higher education, we have Western Reserve University, with its eight departments, and the Case School of Applied Science; also a good School of Art; and before the year closes will be opened the Cleveland Museum of Art, a beautiful marble building in Wade Park. The city is rapidly extending its system of playgrounds, and is encouraging the use of its parks. There are more than 2,000 acres of public parks, with 41 miles of connecting boulevards. With the recent adoption of Eastern Time in Cleveland, which gives us an hour more of daylight after working hours, it is surprising to note the increasing number of people that avail themselves of the opportunity of out-door recreation in the parks.

Two things more I must mention before releasing you. It is not often that a citizen of Cleveland gets so good an opportunity to talk about the city of his birth, of his home and of his affection; but I feel that I must make mention of the public libraries of Cleveland, because statistics show that Cleveland stands third in the number of volumes issued from the public libraries, and first in the circulation of books per capita of its inhabitants.

CLEVELAND'S "GROUP PLAN."

Lastly, I wish to speak of Cleveland's group plan, which reflects the progressive spirit of the people, as our city I think was the first in America to undertake the erection of its public buildings in a related group. Our group plan was prepared by three of America's greatest architects. The Federal buildings will be grouped about a mall or broad parkway, extending from Superior Avenue to the new Union Depot at the lake front. The Federal building and the County Court House are finished and occupied, and the City Hall is nearing completion. Plans for a new Union Depot have been agreed upon, and the voters are to cast their ballots on November 2 of this year, upon the sale of city property to railroads for its site. Two million dollars has been voted for a new Public Library building, and its construction will commence in the near future.

All of these factors that I have mentioned have, I think, a direct bearing upon the future industrial growth of this city. I think it reflects the character and spirit of its citizens. The fundamental conditions for a vast and rapid growth in Cleveland are, I believe, ideal. (Applause.)

PRESIDENT GARY: Is there any discussion of Mr. Mather's paper? (After a pause.) We shall now have a paper on Modern Methods of Burning Blast Furnace Gas in Stoves and Boilers, by Mr. Ambrose N. Diehl, who, since our last meeting has been promoted to be Assistant General Superintendent of the Carnegie Steel Company, Duquesne, Pa. (Applause.)

MODERN METHODS OF BURNING BLAST FURNACE GAS UNDER STOVES AND BOILERS

AMBROSE N. DIEHL

Assistant General Superintendent, Carnegie Steel Company, Duquesne, Pa.

OUTLINE.

The proper presentation of the topic suggested by the program committee of the Institute is almost as difficult as the problem itself. It may be best to approach the subject

by a brief description of blast furnace gas, and then outline the methods in use under the subdivisions of stoves and boilers, and describe them in connection with the various confirming tests and practices employed. While volumes of tests have been published on coal-fired boilers, it is extremely difficult to find very much accurate and authentic data on those using blast furnace gas. Therefore it might be well for the published transactions to contain a number of such tests in detail, as observed by experienced steam engineers of several of the principal plants of the United States Steel Corporation. For this reason there are included some tests both of stoves and boilers in greater detail than necessary in the text of this paper.

From carefully calculated heat balances it is shown that about 48 per cent. to 50 per cent. of the thermal value of the fuel used in the blast furnace passes from the top in the form of sensible and latent heat in the gas. Our efforts to lower fuel ratios, aside from raw material improvement, have been principally in increasing hearth temperatures. This increment is best obtained by hotter blast, requiring better and more efficient contact with the brick-work of the stove. To accomplish this about 30 per cent. of the gas generated per ton of iron is used, allowing 60 per cent. to be used in boilers or engines and a 10 per cent. loss. The desire for higher heats thus forced into prominence better stove construction and better combustion as an indirect means of lowering coke consumption. However, the saving of 12.3 cents per ton of iron, by increasing boiler efficiency from 55 per cent. to 65 per cent. in burning the other 60 per cent. of the gas, has been almost overlooked. It has been only recently that anything but spasmodic furnace-gas boiler tests have been made, and these only for passing information. Practically no recognition was given them, except to acknowledge conditions were bad, and but few attempts were made to correct the discrepancies which the tests revealed. The tests seldom reflected usual operations, since boilers were often

overhauled and repaired before starting, thus giving erroneous ideas of the general prevailing condition.

Although great savings are possible by the efficient burning of blast furnace gas, yet to the minds of the majority of operators it was a problem of minor importance, as pig iron was the commodity desired and the gas at best only a necessary adjunct. Coupled with this idea was the fact that all furnaces will produce more than enough gas for their own auxiliary power equipment even with the crudest boiler arrangements. So it would not be worth while to expend thought or capital for unnecessary efficiency for the privilege of opening the bleeder a little further. This accounts for so little engineering judgment used in many boiler installations.

Blast Furnace Gas.

Blast furnace gas consists essentially of the unoxidized carbon monoxide remaining from the primary combustion of the coke in the hearth. As the air comes in contact with the incandescent fuel at the tuyeres the oxygen and carbon form theoretically an unsaturated gas, CO, with reducing properties, and at a high temperature. As the CO comes in contact with the descending oxides it is partly oxidized to CO_2, but still contains sufficient CO to make it a valuable asset for heating and power purposes.

An average blast furnace gas on Lake ores has approximately the following analysis by volume:

CO_2	12.5%
CO	25.4
H_2	3.5
Hydro Carbon	0.0
Nitrogen	58.6

This gas will have a thermal value at 62° F. and 30″ Bar. of 92.0 B.T.U. The gas further contains about 30 to 35 grains of water per cu. ft., depending on the water in the charge, either from material sources or used for dampening. The temperature of the gas varies with the driving, combustion and length of contact with the stock through which it passes.

Flue Dust.

Fine ores, coke and limestone dust are mechanically carried in suspension in varying quantities, depending on the physical condition of the charges, the velocity of gas, and movements of the stock. In every plant a first provision is to remove the heavy material by an enlargement of the gas flue, or dust-catching chamber, where the gas velocities are decreased and the gas forced to change direction. This will tend to deposit the heavier and coarser material, while the finer divided and lighter will be carried on and deposited in the flues, or escape to the atmosphere through the stacks of the stoves or boilers. A proportionate percentage of the deposited dust, with the physical condition of the same, is approximately as follows:

ANALYSIS.

SiO_2	Fe.	P.	Mn.	Al_2O_3	MgO	H_2O	C.
8.19%	38.89%	.069%	.51%	2.52%	.31%	14.30%	12.87%

Percentage of total dust carried beyond dust catcher = 28%
Fineness " " " " " " " = 92% through a 300-mesh screen.

Naturally these conditions are subject to the variations of each local installation, as the number of pockets, sizes of dust catcher and flues, together with the quantities and velocities of gas, will influence the disposition of the dust.

Moisture.

The moisture is present as vapor, and, if the temperature of the gas is lowered beyond the dew point, water will be accordingly deposited, as the gas will remain in a saturated state. This condition arises only with highly wetted charges, unusually low gas temperatures, cold atmosphere, or high radiation.

This constitutes our dirty gas which is conducted to the stoves and boilers in our past and present practice.

Clean Gas.

Within the past few years the economy of higher heats, as well as the repairs and expenditures in stove

practice, have most clearly demonstrated the economic value of further cleaning the gas. This can be done in various ways. A dry filtration method has been working with apparent success on the Continent, but does not have to contend with the large percentage of fines which the American Mesaba practice has to contend with. Wet mechanical washers are in use, but the simplest is a spray tower with provisions for the prevention of gas channelling. It is necessary in this case to use sufficient water to not only remove the dust, but also to cool the gas low enough to remove excessive moisture. If the gas is not cooled after being subjected to water contact, the moisture content is such as to either prevent combustion or carry the thermal losses in the stack so high as to make the operation decidedly uneconomical. By proper washing, the dust is lowered from 3 grains to approximately .2 grains per cu. ft., and the moisture from 30 grains to 8 to 10 grains. The lowering of the gas temperatures from 300 degrees to 80 degrees robs it of 220 degrees of sensible heat, which is balanced by the gain due to reduction of moisture and dust and the resulting cleanliness of heating surface. Tests conducted at Duquesne show that equally high flame temperatures can be obtained from either clean or dirty gas. The average combustion chamber temperature from 19-24 hour tests on clean gas was 2040° F., and from 8-24 hour tests on rough gas, 2030° F.

Combustion.

Blast furnace gas is made to yield its energy in three principal ways:

1st—By combustion in recuperating chambers or stoves for the purpose of pre-heating the blast.

2d—By combustion under boilers for steam generation.

3d—By combustion in gas engines for blowing or power generation.

In all of the above divisions, the first principle to be applied is the supplying of sufficient oxygen to just com-

plete the oxidation of the several combustibles present. Excess of air results in the dilution of the products of combustion, consequently in the lowering of flame intensity and the carrying away of a corresponding quantity of heat units in the stack gases. Insufficient air results in the lowering of flame intensity due to incomplete combustion, and the loss of calorific value of the gas in the stack is not compensated for by the gain due to the lesser weight of the flue gas. Thus it is obvious that for efficient combustion a proper mixer or burner is of primary importance.

Requirements of Burner.

There have been very few operators who have not at one time or another put one or more pipes through a stove or boiler burner in order to get the so-called Bunsen effect. In the case of stoves these experiments generally terminated in two results. First, if the air-duct was sufficiently large to effect any decided change, the temperature of combustion was considerably increased and resulted in the flue dust carried with the gas fluxing with the brick in the combustion chamber, and either boring a hole through the same or filling the well with semimolten or plastic material. Second, the stove from which a high temperature was obtainable, at first, ran down quickly, resulting in the operator's statement that the stove merely had a "flash temperature, but would not carry its heat." The air-pipes generally occupied so much area that the normal supply of gas was decreased in consequence, and an insufficient thermal capacity resulted. These efforts mostly resulted in failure, on account of the foregoing causes, and, instead of burning down stoves by flame concentration, air was allowed to enter through special doors or blow-off valves. In this manner the proper mixing was intentionally spoiled and the consequent flame temperature lowered, to preserve the walls from the subsequent fluxing action. Much of

this difficulty is avoided in burning clean gas, and the temperature can be raised to its highest limit.

In the case of boilers, especially if air shortage was the prevailing condition, the placing of pipes or other aspirating devices around or through the burner occasionally resulted in small increases in efficiency, due to supplying more nearly the required amount of air.

Burner Efficiency compared to Boiler or Stove Efficiency.

In the testing and development of gas burners, the performance of the burner itself is of much greater interest and importance than that of the combined unit of burner and stove or boiler. On account of the difference in design of the different types, and the difference in condition and performance of the same type and even in the same installation, it is both unfair and unreliable to judge the worth of a burner upon the basis of the combined efficiency of the stove or boiler on which it happens to be tested. The results obtained in this way have a direct application, at best, only to a similar type and size of the boiler or stove tested, and even then are not free from the inaccuracies which frequently occur in all but the most exact and pretentious forms of testing. For these reasons it has been considered advisable to suggest the term "Burner Efficiency"—to define a standard by which the qualities of a burner alone may be judged, and to develop methods of testing with that object in view.

Burner Efficiency of 100 Per Cent.

It is apparent that an ideal burner will admit the theoretically correct quantities of air and gas, and completely mix them, thereby producing a maximum flame temperature at the point of ignition. The performance of a burner, on the basis of this ideal condition, may be determined by the observation of flame temperature, and by analysis of products of combustion, both methods being useful in practice. A couple, inserted in the combus-

tion chamber close to the point of ignition, furnishes both quick and reliable indications for the adjustment of air and gas openings in the burner to continuously produce the best state of combustion. The highest temperature obtained in this way is not necessarily the theoretical maximum, but merely the maximum that can be produced by the burner under the prevailing conditions. The observed temperature will be affected by the radiation from surrounding bodies and the possible presence of CO in the products of combustion. The calculated theoretical temperature will depend on the moisture in the gas and the accuracy of specific heat constants used. Therefore temperature observation cannot be an absolute standard of burner efficiency, and a method based on analysis of products of combustion must be used. If the products analyze carbon dioxide and nitrogen, with no oxygen or carbon monoxide, the combustion is perfect and mixing of the burner may be called 100 per cent. efficient. The next factor to be determined is at what point in the path of the gases this perfect condition should be reached. Theoretically, it is directly at the outlet of the burner or ignition point, and a combination of these conditions would give a theoretical burner efficiency of 100 per cent. Practically, this is very difficult to obtain, and we must assume a point a short distance beyond the burner, but well in front of the first heat absorption surface. It is therefore suggested that, as a standard, a point two feet beyond the point of ignition be adopted as the point at which gas samples shall be drawn for a determination of burner efficiency, a water-cooled sampling tube, of course, being used. The definition therefore becomes: "A mixing gas burner is operating at 100 per cent. combustion efficiency when the analysis of a sample, drawn from a point two feet beyond the point of ignition, shows perfect combustion."

The next step is the calculation of the efficiencies less than 100 per cent. The basis is the calorific value of the fuel gas, and the loss is the calorific value of the unburnt

CO present, plus the sensible heat contained in the excess air at the combustion temperature. The difference between the basis and the loss, divided by the basis gives the burner efficiency.

For example: Assume—

Combustion Chamber Analysis.

CO_2	24.5%
O_2	0.5
CO	0.7
N_2	74.3
Temp.	2050° F

Furnace Gas Analysis.

CO_2	15.0%
CO	24.3
H_2	3.3
N_2	57.4
B.T.U.	88.0

$$\text{CO loss} = \frac{39.3}{25.2} \times .007 \times 324 = 3.5 \text{ B.T.U.}$$

$$\text{Air excess} = \frac{(15.0 + 24.3) \times (0.5 - \frac{1}{2} \times 0.7)}{(24.5 + 0.7) \times \frac{1}{2}\,(24.3 + 3.3)} \times 100 = 1.69\%$$

$$\text{Air required} = \frac{\frac{1}{2}\,(24.3 + 3.3) \times 4.78}{100} = .66 \text{ Cu. Ft.}$$

Air excess $= .0619 \times 0.66 = .0112$ Cu. Ft.

Sensible heat $(2050° - 62°) = 41.3$ B.T.U. Per Cu. Ft.

" " Air Excess $= .0112 \times 41.3 = 0.5$ B.T.U.

Total loss $= 3.5 + 0.5 = 4.0$ B.T.U.

$$\text{Burner efficiency} = \frac{88.0 - 4.0}{88.0} = 95.5\%$$

By this means, independent judgment may be passed upon the burner, freed from misleading statements of boiler efficiency, as well as from the indefinite figure of "Pounds of steam per pounds of coke consumed" which has been advanced.

After perfect combustion has been attained, the remaining problem is one purely of boiler construction and heat absorption, precisely as in a waste heat boiler, and is quite apart from an investigation of burners.

As the efficiency of a boiler varies with the load so will the efficiency of a burner. Some burners are highly efficient at low loads, others at high loads, and the main problem is to develop a burner that will closely approach perfection at boiler ratings from 75 per cent. to 200 per cent. The principal requirement is maximum flame temperature and the most positive way to get it is by a perfect mixture of air and gas in the burner.

With the foregoing method, definite judgment may be passed on the comparative merits of different burners, but the question "Which, if any, special mixing burners would be advantageous?" is one which must be decided on a knowledge and appreciation of the details of equipment and operating conditions of the plant involved. If a boiler or stove has favorable conditions of pressure and draft, and a large mixing chamber, it may operate at a combustion efficiency approximately as good as could be obtained from the best mixing burner, in which case, new burners would not pay interest on the investment. Such operation is exceptional and generally requires very close regulation to obtain equally good results. With the advent of clean gas the majority of furnace operators feel the need of mixing burners, and in such cases, where a comparison of burners is the problem, the most reliable and comprehensive information will be obtained by methods of test and calculation leading to the determination of Burner or Combustion Efficiency. Unfortunately there is not sufficient data available to compare the burners, discussed in this paper, on this basis. Therefore, the combined stove and boiler efficiencies must be resorted to. While this is not satisfactory, as has been stated before, at least in regard to sensible heat loss, the fact remains beyond all dispute, that the presence of CO in the stack gases indicate very clearly the lack of mixing qualities of a burner.

Flame Intensity.

Heat exchange betwen bodies of different temperatures varies in proportion to their means, and provided there is a sufficient heating surface the products of combustion will evidently impart a higher ultimate temperature to the absorbent if the initial temperature is high than if the combustion were such that a lower initial temperature were attained. The absorption of heat by the brick-work during the heating operation is also facilitated by high temperature due to the greater rate of

absorption in the combustion chamber and top of the checker chamber, resulting in a necessarily lower stack temperature with equal quantities of gas and equal heating surface. Boiler heat absorption follows the same rule, except that the temperature of the heat absorbent, or of the tubes, is constant, while in the stoves the temperature of the brick absorbent is variable. On account of the greater difference in temperature, the heat in the gas can be absorbed far more quickly in the boiler, therefore in this case so much less surface is required.

CLASSIFICATION.

Blast furnace gas burners may be classified under six general types as follows:

1st—Rectangular or circular nozzle burner with air added, around it, or by separate air doors or a combination of both.

2d—Rectangular or circular burner with air conducted into the gas jet by means of pipes or other openings.

3d—Burner which subdivides air and gas into separate streams which do not mix in the burner.

4th—Burner into which air is aspirated by means of an air jet at high pressure, as in a steam jet blower, the air from both sources mixing with the gas in the burner.

5th—Burner through which all of the required air is forced and completely mixed with the gas before the ignition point.

6th—Burner to which air and gas are supplied after being perfectly mixed in a fan which admits air on one side and gas on the other, discharging the mixture into a common outlet.

The foregoing has been a discussion of the general features of blast furnace gas combustion. From this point stoves and boilers will be taken up separately in

the consideration of burner design and operating conditions, since the method of procedure is somewhat different in the two cases.

Stoves.

The combustion chamber of a stove is long, and therefore tends to produce a good mixture before the checkers are reached. However, by completely mixing the air and gas in the burner before the ignition point, the maximum flame temperature is obtained, and the total path of the gases through both combustion chamber and checkers is utilized to the fullest extent for heat absorption.

The temperature curves of a stove,* given in Mr. Maccoun's paper on Blast Furnace Advancement read at our May meeting, illustrate the point mentioned, and shows an average temperature of 1900° at the burner opening, reaching temperature half way up of 2150° and decreasing to 2040° at the top of the combustion chamber. With this form of burning high CO losses would have resulted, had the combustion chamber been short.

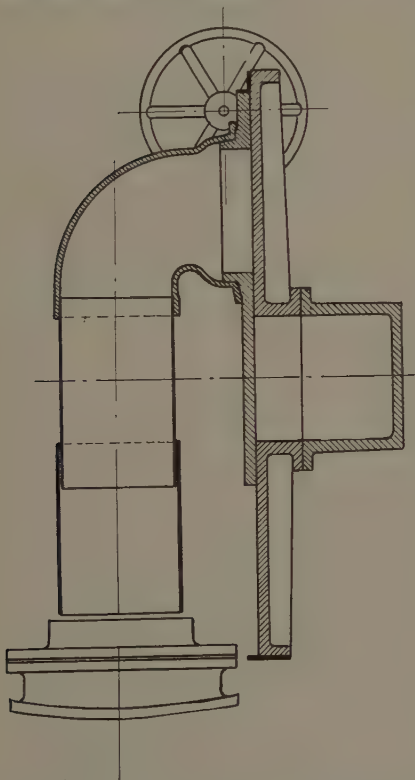


Fig. 1. Kennedy Stove Burner

Several stove burners of various types in regard to which information is at hand will be enumerated and described under headings of their general characteristics.

Type 1.—Rectangular or circular nozzle burner with air added around it or by separate air doors or both.

*See figure 6 on page 337 of this volume

This is the burner in common use in nearly all blast furnace stoves and is exampled by the Spearman-Kennedy burner (Fig. 1). The air is taken in through the clearance space around the burner and through doors in other parts of the stove circumference. The gas and air meet and mix in passing up through the combustion chamber. If the correct quantities have been admitted, the great length of combustion chamber permits the practical completion of burning before the checkers are reached. Extracts from tests of stoves, using the common burner, made at Duquesne and Edgar Thompson Works, clean gas being used in both, follow:

Item.		*Duquesne*	*Edgar Thompson*
Type of Stove		2-pass central Combustion Chamber.	2-pass
Size of Stove		21′ × 96′	22′ × 100′
Heating Surface, sq. ft.		39,920	51,192
Cubic Contents, sq. ft.		17,974	8,894
Air Blown Per Minute at 62°, cu. ft.		40,580	37,744
Temperature Hot Blast, degs. F.		1,076	1,200
Temperature Stack, degs. F.		612	537.5
Time on Gas, mins.		198.75	172.25
Time on Blast, mins.		64.0	60.0
Furnace Gas Analysis	CO_2	13.06	11.94
	CO	25.78	24.84
	H_2	3.69	4.45
	N_2	57.47	59.77
Flue Gas Analysis	CO_2	21.30	18.08
	O_2	2.90	4.93
	CO	.8	0.0
	N_2	75.0	76.99
Heat Absorbed by Blast (Efficiency), per cent.		64.48	58.04
Sensible Heat Lost in Flue Gas, per cent.		22.22	23.41
Unconsumed CO Loss, per cent.		4.52	0.0
Radiation, Unaccounted for, etc., per cent.		8.78	18.45

In these tests the stack analyses are good and the temperature comparatively low. However, both could be somewhat improved by careful regulation, to give approximately as good stack analyses as have been obtained with the use of mixing burners. This point is illustrated by the following figures, from tests of stoves at Wisconsin Steel Company, where the operation is under constant technical supervision. Clean gas was used.

Type of Stove		Kennedy 2-pass.
Size of Stove		22′ × 90′
Heating Surface, sq. ft		33,000
Air Blown Per Minute at 62°, cu. ft		35,000
Temperature Hot Blast, degs. F		1,165
Temperature Stack, degs. F		761
Time on Gas, min		236
Time on Blast, min		73
Furnace Gas Analysis	CO_2	15.1
	CO	23.6
	H_2	3.0
	N_2	58.3
Flue Gas Analysis	CO_2	25.0
	O_2	1.0
	CO	0.0
	N_2	74.0
Heat Absorbed by Blast (Efficiency), per cent		61.5
Sensible Heat Loss in Flue Gas, per cent		26.5
CO Loss in Flue Gas, per cent		0.0
Radiation and Unaccounted for, per cent		12.0

The stack analysis here shown is excellent. The high stack temperature is the result of insufficient heating surface, since the combustion is as good as could possibly be obtained in regular operation.

Type 2.—Rectangular or circular burner with air conducted into the gas jet by means of pipes or other openings—illustrated in the Landgrebe burner (Fig. 2) developed at the T. C. I. & R. R. Co., Ensley, Ala.

This burner consists of 21-4″ boiler tubes through which the gas is admitted. The outer row of tubes is

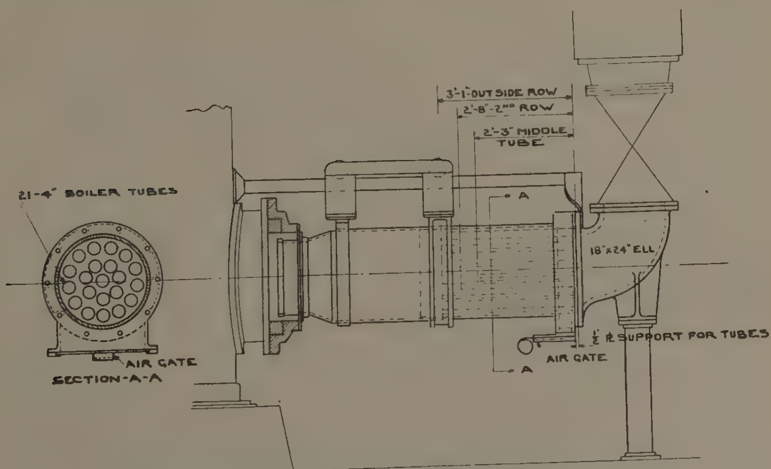


Fig. 2. Landgrebe Burner for Blast Furnace Gas

the longest, the center tube the shortest, and the middle row is cut half way between, so that the gas flowing through the central tube starts burning before any of its neighbors. Surrounding these tubes is an air space formed partly by the outer shell of the burner and partly by a sliding sleeve which tightly connects the main burner with the stove door frame when the door is removed. The ends of the gas tubes are placed about two feet from the door frame. Air is admitted at the back of the gas tubes surrounding them, and at the ends of the latter meets the gas, at which point mixing takes place. To eliminate the necessity of disturbing the relation of gas and air supply, if it became necessary to increase or decrease the flow of gas, a separate gas valve was supplied in the pipe connection to the gas main. This gas valve is simply a cylindrical valve covering a port and consisting of special mechanical features to prevent clogging and leakage and to insure ease of operation. Thus the supply of gas can be regulated at will without disturbing the burner proper. Suitable slides, etc., are provided for regulating admission of air into the air chamber of the burner.

Burners of the above description were provided for two new two-pass side combustion stoves, 22′ × 110′ which were built and put into service in January, 1912. A series of tests were conducted on these stoves while they were still new and clean, and the results of these tests, though variable, were, on the whole, quite satisfactory.

An exhibit of these tests follows:

Type of Stove		2-pass.
Size of Stove		22′ × 110′
Heating Surface, sq. ft.		
Cubic Contents, cu. ft.		
Air Blown Per Minute at 62°, cu. ft.		49,700
Temperature Hot Blast, degs. F.		1,200
Temperature Stack, degs. F.		437
Time on Gas, mins.		205
Time on Blast, mins.		55
Furnace Gas Analysis	CO_2	10.92%
	CO	32.72
	H_2	1.04
	N_2	54.56
	CH_4	.16

Flue Gas Analysis	CO_2	24.40%
	O_2	1.70
	CO	0.0
Heat Absorbed by Blast (Efficiency), per cent		74.1
Sensible Heat Loss in Flue Gas, per cent		13.2
CO Loss in Flue Gas, per cent		0.0
Radiation and Unaccounted for, per cent		12.7

Both stack analysis and temperature are excellent and as good as could be obtained with any type of burner, since they are very close to the theoretical possibilities. The secret of success in a burner of this type seems to be the design of air-ports sufficiently large to take care of the quantities required for complete combustion.

Another example of this form is found in the Boynton burner in use at the Lorain Works, of the National Tube Company. (Fig. 3.)

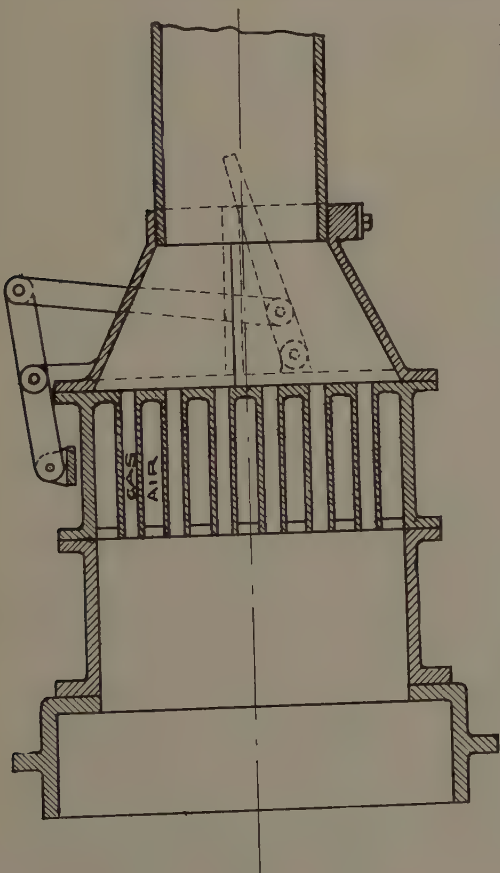


Fig. 3. Boynton Gas Burner

Air and gas are admitted in horizontal layers as shown in the sketch, this stratification being produced with the idea of obtaining intimate mixture of air and gas at the point of admission.

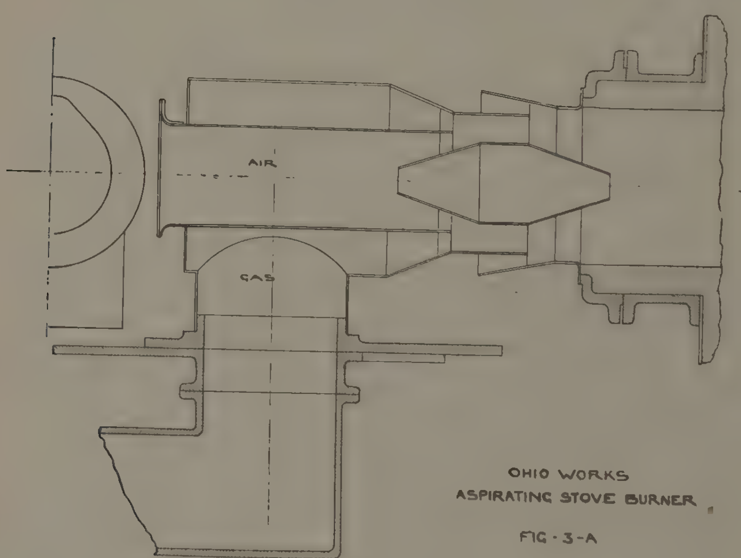
The following analyses, taken without any regulation, and without knowledge of the hot blast men, from seven different stoves operated by three different men, show good operation, but give no indication as to just what point in the stove the com-

pletion of mixture takes place or of the resulting stack temperatures.

ANALYSES OF FLUE GAS FROM HOT BLAST STOVES.

Date	Furnace	Stove	CO_2	O_2	CO
Oct. 26	No. 2	No. 2	25.0%	0.0%	0.6%
" "	2	3	26.0%	0.0%	0.2%
" "	2	4	25.8%	0.0%	0.6%
" 27	5	2	24.6%	0.8%	0.0%
" "	5	3	25.8%	0.2%	0.2%
" "	2	1	26.0%	0.0%	0.2%
" "	2	2	26.0%	0.0%	0.8%
" "	2	3	25.6%	0.4%	0.0%
" "	2	5	25.8%	0.2%	0.2%

Of the same type is the aspirating stove burner developed at the Ohio Works of the Carnegie Steel Company, illustrated in Fig. 3-A. By means of this burner



OHIO WORKS
ASPIRATING STOVE BURNER

FIG-3-A

the same blast heats have been obtained with a consumption of 4900 cu. ft. gas per minute as compared to 5740 cu. ft. with the common goose-neck burner. Since stack temperature and analyses on the two burners are about equal, this gain must be credited to the better absorption

which is due to faster mixing obtained with the aspirating burner. Comparative tests of these burners follow:

			Common	Ohio Works
Type of Stove			2-Pass	2-Pass
Size of Stove			21′x115′	21′x115′
Heating Surface		Sq. Ft.	53,700	53,700
Cubic Contents		Cu. Ft.	5,349	5,349
Air blown per Min. at 62°F.		" "	39,600	39,600
Gas burned per Min. at 62°F.		" "	5,740	4,900
Temperature of Hot Blast		Deg. F.	1,200	1,200
Temperature of Stack		" "	800	780
Time on Gas		Minutes	170	170
Time on Blast		"	60	60
Furnace Gas Analysis	CO_2	%	12.9	12.9
	CO_2	%	26.4	26.4
	H_2	%	3.4	3.4
	N_2	%	57.3	57.3
Flue Gas Analysis	CO_2	%	24.5	24.0
	O_2	%	0.0	0.7
	CO	%	0.8	0.0
	N_2	%	74.7	75.3
Heat Absorbed by Blast (Eff.)		%	56.4	59.7
Sensible Heat Lost in Flue Gas		%	29.5	30.3
Unconsumed CO Loss		%	4.1	0.0
Radiation Unaccounted for, etc.		%	10.0	10.0

Type 3.—Burner which subdivides air and gas into a series of streams which do not mix in the burner.

A stove burner, answering this description, has been developed at the Edgar Thompson Works, Carnegie Steel Company (Fig. 4). This burner consisted of the usual burner base box carrying the burner base. This burner base is a casting containing the gas and air-admission passages, and ports for the burner, and having a cylindrical seat or face. The burner seat consists of a casting having a cylindrical face fitting onto the corresponding face of the burner base and free to rotate over the same. This casting is provided with gas and air ports, and passages, gear teeth for rotating the same, and flanges for supporting the burner nose or nozzle. The burner nozzle bolted to the burner-seat casting consists of two concentric barrels, 3 ft. long, forming the gas and air passages. The central or gas passage, 14½″ in diameter, contains a spirally twisted vane, twisted through about one and one-half turns; the outer or air passage, 4½″ wide, contains four spiral vanes, making one-half turn

each and twisted in the opposite direction from the gas vane. The vanes run the full length of the barrel. The entire nozzle is built of sheet iron and boiler plate. Slid-

Fig. 4. Edgar Thomson Stove Burner.

ing lengthwise on the outside of the barrel is a short nozzle, actuated by a system of levers and links, and used to complete the connection between the burner and the branch connecting to the combustion chamber. The burner seat and nozzle are rotated in a vertical plane by means

of a hand-wheel and gears, the center line of the burner barrel being practically vertical when the gas is off, and making an angle of about 49° with the horizontal when the gas is on the stove. A steel casting is lined with fire brick, leaving a conical opening into the combustion chamber; the central axis of the cone lies in a vertical radial plane through the center of the stove and makes an angle of about 49° with the horizontal, giving as nearly a vertical admission of the flame to the combustion chamber as is possible for a burner at the side of the stove and with the construction of stove tested.

The gas-main supplying gas to the burner was provided with a mushroom type, hand-controlled shut-off and control valve, and a butterfly valve actuated by a pressure regulator.

The following test figures show a decided gain in efficiency over that of the old form of burner mentioned before:

Type of Stove		2-pass.
Size of Stove		22′ × 100′
Heating Surface, sq. ft.		51,192
Cubic Contents, cu. ft.		8,894
Air Blown Per Minute at 62°, cu. ft.		44,748
Temperature Hot Blast, degs. F.		1,119
Temperature Stack, degs. F.		376
Time on Gas, mins.		161.8
Time on Blast, mins.		60
Furnace Gas Analysis	CO_2	11.78%
	CO	26.38
	H_2	3.15
	N_2	58.67
Flue Gas Analysis	CO_2	23.60%
	CO	1.87
	O_2	.45
	N_2	74.08
Heat Absorbed by Blast (Efficiency), per cent		71.58
Sensible Heat Lost in Flue Gas, per cent		10.50
Unconsumed CO Loss, per cent		9.46
Radiation, Unaccounted for, etc., per cent		8.46

A complete test of this stove and burner follows:

1. Number of Test	1
2. Date of Test	May 24th to May 30th, 1915
3. Blast Furnace and Stove Number	G—4
4. Size of Stove	22′x100′
5. Type	Two Pass

6. Heating surface in checkers..........	Sq. Ft.	51,192
7. Cubic Contents in checkers............	Cu. Ft.	8,894
8. Ratio of heating surface to cubic contents of brickwork in checkers....................		5.75 to 1
9. Estimated weight of brickwork in Stove.	Lbs.	3,617,000
10. Estimated weight of ironwork in Stove.	Lbs.	223,000

PRESSURES.

11. Blast furnace gas in main............	Ins. Water	3.48
12. Draft in Combustion Chamber.........	" "	....
13. Draft in Chimney #1.................	" "	1.49
14. " " " #2.................	" "	....
15. " " " #3.................	" "	1.82
16. Average draft in Chimney............	" "	1.66
17. Blast in Main......................	Lbs. Sq. In.	14.85
18. Barometer at 62 degrees Fahr.........	Ins. Hg.	29.163

AREAS.

19. Burner Opening......................	Sq. Ins.	159.48
20. Area of Gas Leg.....................	" "	133.36

TEMPERATURES.

21. Blast Furnace Gas in Main............	Degs. F.	75.46
22. Cold Blast in Main...................	" "	173.56
23. Hot Blast in Main....................	" "	1119.0
24. Chimney Gases Chimney #1 (Min.).....	" "	300.0
25. " " " #1 (Max.)....	" "	475.0
26. " " " #1 (Average).	" "	387.0
27. " " " #2 (Min.).....	" "	.....
28. " " " #2 (Max.).....	" "	.....
29. " " " #2 (Average).	" "	.....
30. " " " #3 (Min.).....	" "	290
31. " " " #3 (Max.).....	" "	450
32. " " " #3 (Average).	" "	365
33. Chimney Gases. Average for all chimneys	" "	376
34. Atmospheric. Wet Bulb..............	" "	60.38
35. " Dry Bulb..............	" "	66.61

DURATION.

36. Time Stove on Gas...................	Hours.	93.242
37. Time Stove on Blast..................	"	34.567
38. Total elapsed time for Test...........	"	133.750

GAS.

39. Heat value per cu. ft. of dry gas at 62° F. and 30″ Hg. (Gross)............	B.T.U.	95.80
40. Grains of moisture per cu. ft. at 62° F. and 30″ Hg......................	Grains	6.91
41. Grains of moisture per cu. ft. as actually existed in main..................	"	58.0
42. Total gas consumed at condition in main.	Cu. Ft.	24,918,753
43. Total gas consumed at 62° F. and 30″ Hg.	" "	23,740,096
44. Gas consumed per minute at temperature and pressure in main...............	" "	4,454
45. Gas consumed per minute at 62° F. and 30″ Hg.	" "	4,243
46. Total moisture in gas consumed........	Lbs.	23,424

47. Grains of dust per cu. ft at 62° F. and 30″ Hg.	Grains.	.2902
48. Grains of dust per cu. ft. as actually existed in main	"	.2765
49. Total dust in gas consumed	Lbs.	1,071
BLAST.		
50. Total air blown at conditions in main	Cu. Ft.	56,037,652
51. Total " " " 62° F. and 30″ Hg.	" "	92,808,300
52. Total air blown per minute at 62° F. and 30″ Hg.	" "	44,748
53. Grains of moisture per cu. ft. at conditions in main	Grains.	8.55
54. Total dry air heated	Lbs.	7,045,003
55. Total moisture heated	"	68,413
ATMOSPHERE.		
56. Grains of moisture per cu. ft.	Grains.	5.16
57. Humidity	Per cent.	70.66
TOTAL QUANTITIES.		
58. Total weight of dry gas consumed	Lbs.	1,781,192
59. Total weight of dry air heated for blast	"	7,045,003
60. Total weight of moisture heated for blast	"	68,413
61. Total weight of blast	"	7,113,416
EFFICIENCY.		
62. Total heat absorbed by blast	B.T.U.	1,597,835,522
63. Total heat generated (corrected for sensible heat in gas above 62° F.)	"	2,232,213,555
64. Efficiency	Per cent.	71.58
FUEL GAS ANALYSIS.		
65. CO_2	% Volume.	11.78
66. CO	" "	26.38
67. O_2	" "	0.00
68. H_2	" "	3.15
69. N_2	" "	58.69
STACK GAS ANALYSIS.		
70. Stack #1—CO_2	% Volume.	23.54
71. " #1—CO	" "	1.66
72. " #1—O_2	" "	0.47
73. " #1—H_2	" "	0.16
74. " #1—N_2	" "	74.17
75. " #2—CO_2	" "	.....
76. " #2—CO	" "	.....
77. " #2—O_2	" "	.....
78. " #2—H_2	" "	.....
79. " #2—N_2	" "	.....
80. " #3—CO_2	" "	23.66
81. " #3—CO	" "	1.70
82. " #3—O_2	" "	0.43
83. " #3—H_2	" "	0.22
84. " #3—N_2	" "	73.99
AVERAGE STACK ANALYSIS.		
85. CO_2	% Volume.	23.60
86. CO	" "	1.68
87. O_2	" "	0.45
88. H_2	" "	0.19
89. N_2	" "	74.08

Type 4.—Burner in which air is aspirated by means of an air jet at high pressure, as in a steam-jet blower, the air from both sources mixing with the gas in the burner.

The Freyn Induced Draft Burner (Fig. 5) is of this type. It consists of a main gas pipe into which two injector nozzles in series are placed. Into the outside nozzle is inserted a small pipe through which high pressure air is supplied. This air operates as the aspirating force, and by its regulation the entire air supply is controlled. This makes a device which is easy to control,

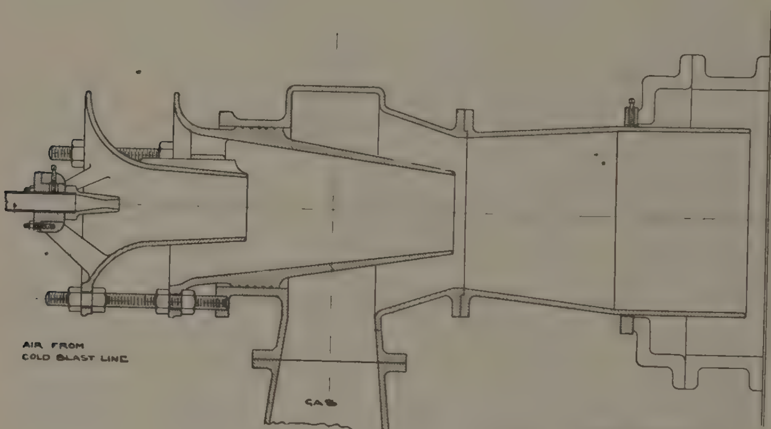


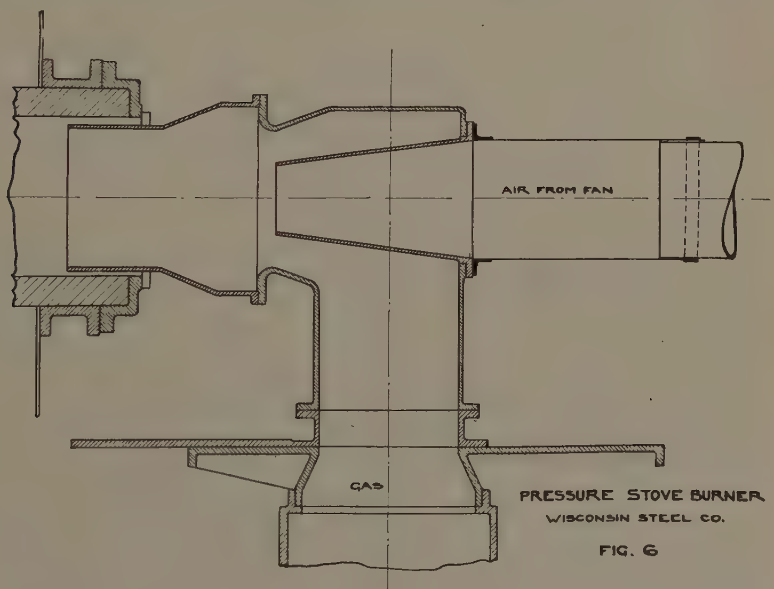
Fig. 5

but not more free from the necessity of control than any other mixing burner. Burners of this form have been placed in use on stoves of the Illinois Steel Company, at South Chicago, but no test data in regard to them is available as yet.

Type 5.—Burner through which all of the required air is forced and completely mixed with the gas before the ignition point.

Burners of this description are in use on the stoves of the Wisconsin Steel Company, at South Chicago, and the American Steel & Wire Company's Central Furnaces, Cleveland, Ohio.

The Wisconsin burner (Fig. 6) consists of a circular gas passage, in the back of which is placed an air nozzle, the air being supplied under pressure by a fan. The old burners on these stoves gave excellent results as mentioned before. However, the heating surface was insufficient, and an additional 4,000 sq. ft. of surface was placed in the combustion chamber. After this change, the draft proved insufficient, and forced draft was resorted to in order to furnish to the stove the required quantity of heat. By this means the capacity of the stove was increased, the efficiency being somewhat higher, as shown by the following test extracts, the stack temperature being lower, but the flue gas analysis essentially the same:



PRESSURE STOVE BURNER
WISCONSIN STEEL CO.
FIG. 6

Type of Stove		Kennedy 2-pass.
Size of Stove		22′ × 90′
Heating Surface, sq. ft		37,000
Air Blown Per Minute at 62°, cu. ft		35,000
Temperature Hot Blast, degs. F		1,273
Temperature Stack, degs. F		598
Time on Gas, mins		55
Time on Blast, mins		148
Furnace Gas Analysis	CO_2	15.1%
	CO	23.6
	H_2	3.0
	N_2	58.3

Flue Gas Analysis	CO_2	24.8%
	O_2	1.3
	CO	0.0
	N_2	73.9
Heat Absorbed by Blast (Efficiency), per cent		69.4
Sensible Heat Lost in Flue Gas, per cent		18.6
CO Loss in Flue Gas, per cent		0.0
Radiation and Unaccounted for		12.0

The forced draft stove burner (Fig. 7) at Central Furnaces, designed by C. A. Orr, consists of an air nozzle inserted in the gas passage. The nose of this nozzle ex-

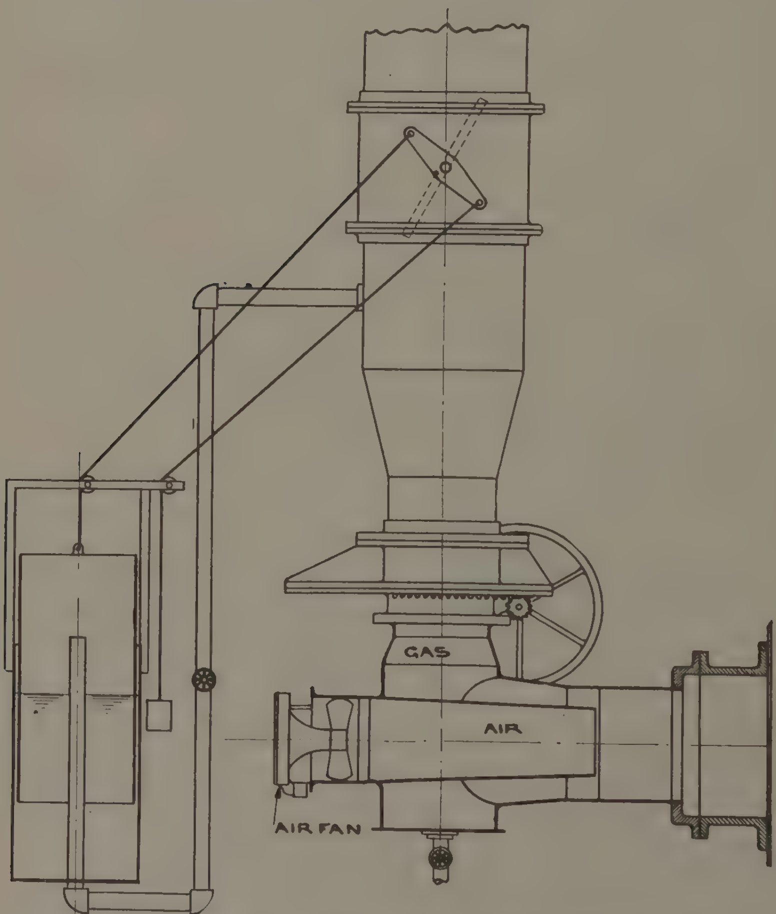


Fig. 7. Forced draft stove burner, Central Furnaces, American Steel and Wire Company

tends to within about thirty inches of the stove connection, and extends back from the downtake a short distance, in which position is placed a 16″ turbo blower, which runs at a constant speed and therefore furnishes the required volume of air at a given rate. In order to insure a correspondingly constant gas volume, a gasometer-controlled damper is placed in the gas downtake about ten feet above the burner. Complete test data for this installation are not available, but the following figures indicate good combustion results.

Time on Gas		120 Mins.
Time on Blast		90 Mins.
Temperature of Blast		1,200° F.
Temperature of Stack		680° F.
Stack Analysis	CO_2	25.5%
	O_2	1.7
	CO	0.0
	N_2	72.8

An approximate heat balance would be:

Heat Absorbed by Blast (Efficiency), per cent	65.0
Sensible Heat Loss in Flue Gas, per cent	23.0
CO Loss in Flue Gas, per cent	0.0
Radiation and Unaccounted for, per cent	12.0

Type 6.—Burner to which air and gas are supplied after being perfectly mixed in a fan which draws in air on one side and gas on the other, discharging the mixture into a common outlet.

An arrangement of this kind is being developed at the present time, but no specific information is available, so it is impossible to speculate on its merits or shortcomings as a mixing device.

SUMMARY OF STOVE TESTS.

Plant.	Type of Stoves.	Size of Stove.	Cu. Ft. air per min. at 62°	Burner.	Eff'cy	Remarks.
Duquesne	2-Pass	21x 96	40,580	Common	64.5	Average operation.
Edgar Thomson	2-Pass	22x100	37,774	Common	58.04	Actual efficiencies probably higher as "radiation and unaccounted for" is excessive.

Edgar Thomson	2-Pass	22x100	44,748	Edgar Thomson	71.58	"Radiation and unaccounted for" normal.
Wisconsin	2-Pass	22x 90	35,000	Common	61.50	Small checker area.
Wisconsin	2-Pass	22x 90	35,000	Forced Draft.	69.40	4,000 sq. ft. checkers added.
Ensley	2-Pass	22x110	49,700	Landgrebe	74.10	Very low stack temperature, and biggest stove listed.
A. S. & W. Co. Cent. Fces.	2-Pass	......	......	Orr	65.00	Detail data not available.

Remarks.

The combustion chamber of large proportions was originally designed primarily as a receptacle for the flue dust carried in rough gas, and secondarily as a necessary aid to combustion under primitive methods of burning. It was also considered advisable to have the hottest checkers at the top, where material strains are smallest, but no doubt, by suitable precautions in design, this factor could be eliminated. The following points should be observed:

Stove Conclusions.

First.—Clean gas should be used when possible.

Second.—Large heating surfaces should be exposed as an aid in lowering stack temperatures.

Third.—Equal drafts and blast distribution over the entire checker area is essential to good practice.

Fourth.—All gas should be consumed in the combustion chamber. The closer the complete combustion is to the burner the better heat exchange is possible.

Fifth.—It is best to add both gas and air at only one point, through the burner, and control them there. Gas and air have channelling tendencies when entered separately.

Sixth.—Forced draft will facilitate flame intensity and act in such manner as to make the combustion of more gas possible in the stove than under atmospheric draft

conditions. If the stove is sufficiently large, considerable advantage can be derived by this method, because greater quantities of gas can be burned in a given time.

Seventh.—It is advisable to make daily flue analyses and have a technical supervision of the combustion.

Boilers.

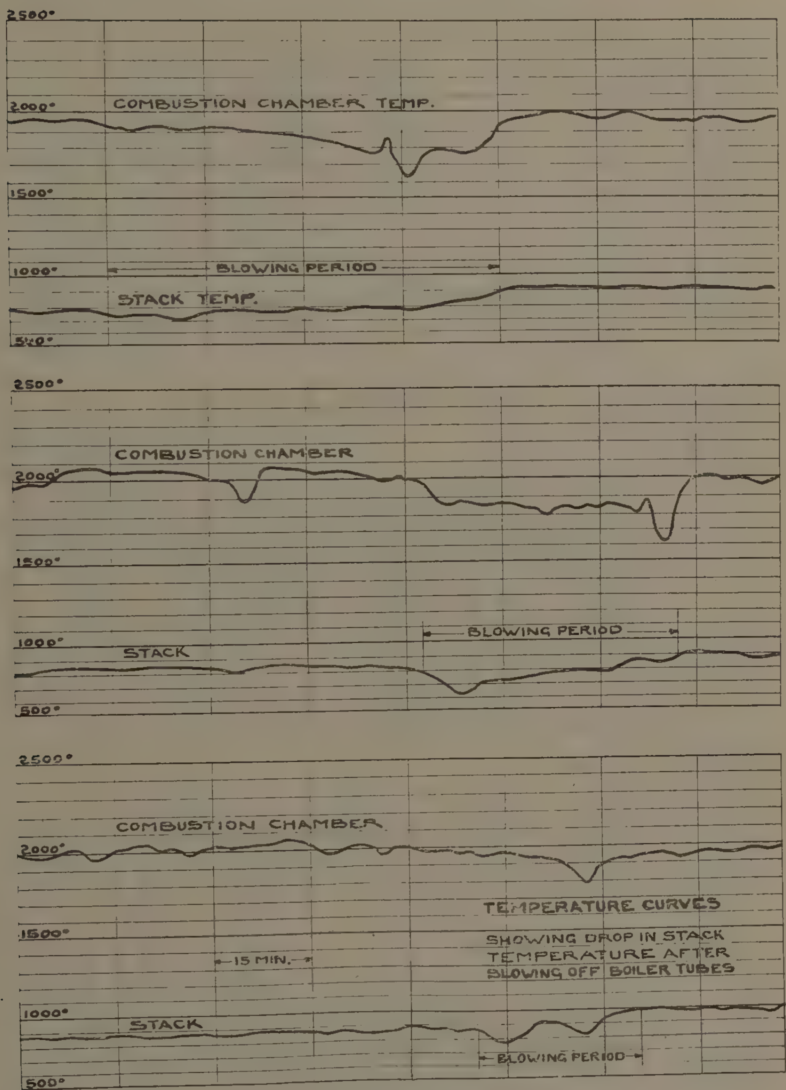
The boilers in operation at the present time in most blast furnace plants are small units, varying, in general, from 250 to 500 H.P. They are usually equipped with feed-water heaters, but rarely with superheaters or economizers. The settings are often leaky and the baffles in bad condition, and in nearly all plants these most important details have been lost sight of until their presence and effect have been demonstrated by observations of flue-gas analyses and temperatures. It would be safe to state that the efficiency of the average blast furnace boiler plant could be increased from 5 to 10 per cent. by the repair and constant upkeep of settings and baffles.

The burner in general use, which will be referred to as the Common Burner, is a burner only in the sense in which the term might be applied to the open end of any gas pipe. The gas enters in a solid rectangle or circle, and the air in a thin layer around it, no pretense being made of completely mixing the two gases before ignition. This work is left to the combustion or mixing chamber, which often, unfortunately, shares the work with half or all of the boiler.

In the operation of this boiler equipment there has been little attempt at scientific regulation. The function of boilers in a blast furnace plant is to burn as efficiently as possible the gas that remains after the constant quantity demanded by the stoves and gas engines have been supplied. The only method of controlling gas pressure and quantity is the butterfly valve placed in the supply line to one or two boilers. The pressure, in a system, where clean gas is used from a central cleaning plant, is controlled from there, upon whose signals the boiler operators vary the positions of the butterfly valves

and therefore the quantity of gas burned in the boilers. This method of control is used in order to insure the required pressure at all times at the gas cleaning plant, and it is proper that the boiler plant should take the variations. This being the case, pressure regulation at the boilers is not to be considered, and the problem is to supply an amount of air always proportional to the quantity of gas available. With most equipments this can be attempted by means of a damper regulation, in combination with sufficient air openings around the burners. The adjustment of dampers, under present operating methods, is given very little attention, and, without intelligent supervision, would be of small value. Probably the best results with the Common Burner would be obtained by automatic damper regulation, controlled by pressure in the gas box between the butterfly valve and the burner. By this means more nearly correct amounts of air and gas would be supplied, thereby decreasing to some extent the losses due to large air excess when gas pressure is low and large quantities of carbon monoxide in the flue gas when the pressure is high. With present equipment, a good mixture of air and gas and the resulting high flame temperature are obtained only by constant and careful attention. However, regular testing is extremely profitable, due to the increased efficiency obtained by repairs to settings and baffles, by regulation of the air supply in so far as this is possible, and because of its tendency to both educate and interest the working force in the matter of efficiency.

When rough gas is used, the regular blowing off of the boiler tubes assumes considerable importance. Observations of stack temperature (with all other conditions constant) before and after blowing tubes show decreases of from 50° to 100° F. (Curve Sheet No. 1) with an average of about 75° F., varying, of course, with the amount of dust in the gas and the volumes of gas burned. There is a loss due to excessive air leakage through open doors while tubes are being blown, and with this fact considered, it appears that the most economical period



Curve Sheet 1

of blowing is every twelve hours, as it is after this length of time that the deposit accumulates rapidly, causing a correspondingly rapid rise in stack temperature. Where rough gas is used, the installation of permanent dust blowers may be found advantageous.

Type 1.—Rectangular or circular nozzle burner with

air added around it, or by separate air doors or a combination of both.

The average efficiency of a blast furnace boiler plant, using common burners and operating without the aid of technical supervision, is not over 50 per cent. and frequently much lower. The losses of 50 per cent. are distributed about as follows: Sensible heat in waste gases, 36 per cent.; CO in waste gases, 9 per cent.; radiation, 5 per cent. This distribution varies greatly with load, gas pressure and position of stack damper. The average

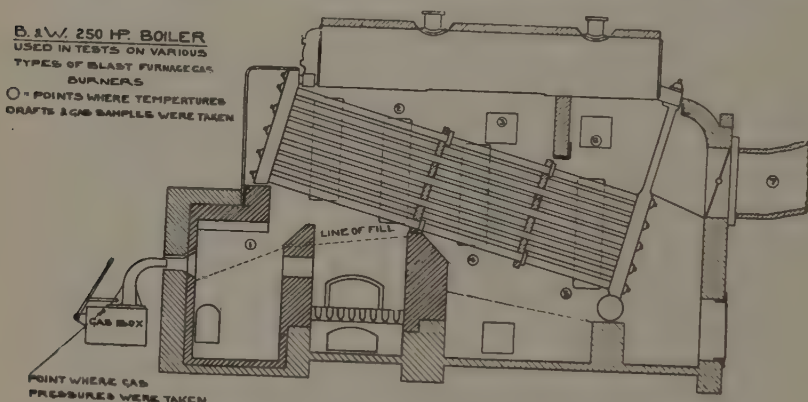


Fig. 8

result of 28 eight hour tests, conducted at Duquesne Blast Furnaces on several 250 H.P., B & W Boilers (Fig. 8), is as follows:

Stack Loss........	35.7%
CO Loss..........	8.4
Radiation	5.0
Efficiency	50.9
B.H.P.	300.0 = 120% builders rating.

While these tests were conducted under operating conditions, the results may be considered slightly better than a continuous average, as observations were suspended during unusual periods, such as very low drops in gas pressure, etc. Also noticeable bad leaks in settings were patched before testing in many cases.

Complete results of these 28 tests follow, which must be considered as studies of combustion rather than regulation boiler tests:

OPERATION OF BOILERS WITH COMMON BURNER.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 2.—250 H.P. B. & W. BOILERS.
PRELIMINARY TESTS TO DETERMINE STATE OF COMBUSTION.

Date		11/21 1913	11/22 1913	11/24 1913	11/25 1913	11/28 1913	11/29 1913	4/2 1915
Boiler No.		12	12	12	12	11	11	9
Style of Burner and Fuel		Common Burner.			Rough Gas.			
B.H.P. Developed		280	280	280	280	280	280	485
Per cent of Rating Developed		112	112	112	112	112	112	194
Furnace Gas Analysis (Dry)	CO_2	12.5	13.2	13.0	13.5	13.8	13.6	14.2
	CO	25.5	26.2	25.5	25.8	26.2	26.2	24.6
	H_2	3.8	3.5	3.5	3.7	3.6	2.8	3.6
Comb. Chamber Gas Analysis (Dry)	CO_2	20.9	21.0	19.6	19.8	21.0	20.4	....
	O_2	0.2	0.6	0.2	0.2	3.0	0.3	....
	CO	7.0	5.7	8.1	8.7	1.5	5.9	....
3rd Pass Analysis (Dry)	CO_2	21.6	20.4	20.5	21.9	20.9	20.9	....
	O_2	2.7	3.7	0.6	0.6	2.0	4.1	....
	CO	0.0	0.9	5.3	2.1	1.1	1.0	....
Stack Gas Analysis (Dry)	CO_2	13.0	14.1	16.1	17.4	14.5	14.8	18.8
	O_2	9.0	8.0	5.9	4.4	7.4	7.5	4.9
	CO	0.0	0.5	3.5	1.8	0.4	0.6	1.8
Ratio { Furnace Gas (Dry) / C. C. Gas (Wet) }		1.50	1.62	1.54	1.51	1.95	1.69	....
Air Excess, 3rd Pass, %		32	46	....	....	18	45	....
Ratio { Furnace Gas (Dry) / Stack Gas (Wet) }		3.04	2.81	2.04	2.14	2.78	2.68	2.0
Air Excess, Stack, %		180	145	55	36	131	130	59
Steam Pressure, Lbs.		152	158	153	142	151	148	143
Gas Pressure, Ins. H_2O		2.8	2.8	2.8	3.1	3.0	2.8	4.0
Feed Water Temperature, °F.		168	169	179	170	171	183	161
Furnace Gas Temperature, °F.		340	350	300	360	370	400	440
Combustion Chamber Temperature, °F.		1865	1895	1690	1730	1725	1890	....
Stack Temperature, °F.		690	665	565	740	710	700	835
Calorific Value of Gas, B.T.U.		93.2	94.6	92.3	93.9	94.9	92.7	89.7
Sensible Heat in Gas, B.T.U.		5.6	5.8	4.8	6.0	6.2	6.8	7.7
Total Heat in Gas, B.T.U.		98.8	100.4	97.1	99.9	101.1	99.5	97.4
Stack Loss per Cu. Ft., B.T.U.		13.2	12.7	10.6	14.2	13.6	13.4	17.9
Stack Loss per Cu. Ft. Fce. Gas, B.T.U.		40.1	35.7	21.6	30.4	37.8	35.9	35.8
CO Loss per Cu. Ft. Fce. Gas, B.T.U.		0.0	4.5	23.1	12.5	3.6	5.2	11.7
Stack Loss, %		40.6	35.5	22.2	30.4	37.4	36.1	36.8
CO Loss, %		0.0	4.5	23.8	12.5	3.6	5.2	12.0
Radiation Loss, %		5.0	5.0	5.0	5.0	5.0	5.0	5.0
Efficiency, %		54.4	55.0	49.0	52.1	54.0	53.7	46.2

OPERATION OF BOILERS WITH COMMON BURNER.
DUQUESNE BLAST FURNACE BOILER HOUSES NO. 1 & 2.—250 H.P.B. & W. BOILERS.
PRELIMINARY TESTS TO DETERMINE STATE OF COMBUSTION.

Date		12/1 1913	12/2 1913	12/3 1913	12/4 1913	12/5 1913	12/6 1913
Boiler & Boiler House No.		#4 — #2 House.			#5 — #1 House.		
Style of Burner and Fuel		Common Burner.			Rough Gas.		
B.H.P. Developed		280	280	280	275	275	275
Per cent of Rating Developed		112	112	112	110	110	110
Furnace Gas Analysis (Dry)	CO_2	12.2	12.0	13.6	12.4	13.4	14.6
	CO	27.0	26.6	26.6	23.2	27.0	25.0
	H_2	3.2	3.8	3.0	3.0	3.8	4.6
Comb. Chamber Gas Analysis (Dry)	CO_2	23.1	22.6	22.0	22.3	22.7	21.8
	O_2	0.5	0.5	1.6	1.8	1.2	0.9
	CO	2.1	3.4	2.0	1.8	3.1	3.8
3rd Pass Analysis (Dry)	CO_2	14.2	14.6	14.1	13.1	13.2	19.3
	O_2	6.9	8.0	8.1	9.9	9.6	2.0
	CO	0.9	0.1	1.0	0.0	0.2	1.0
Stack Gas Analysis (Dry)	CO_2	13.9	14.2	13.4	13.0	12.9	13.0
	O_2	7.3	8.6	8.7	10.0	10.0	9.8
	CO	1.0	1.1	0.9	0.0	0.2	0.3
Ratio Furnace Gas (Dry) / C. C. Gas (Wet)		1.71	1.66	1.86	1.73	1.92	1.96
Air Excess, 3rd Pass, %		110	138	156	205	191	28
Ratio Furnace Gas (Dry) / Stack Gas (Wet)		2.78	2.81	3.12	2.85	3.26	3.16
Air Excess, Stack, %		121	148	174	209	204	202
Steam Pressure, Lbs.		150	152	149	167	168	166
Gas Pressure, Ins. H_2O		3.1	2.4	2.8	....	....	....
Feed Water Temperature, °F.		169	180	171	146	144	152
Furnace Gas Temperature, °F.		370	330	340	350	350	350
Combustion Chamber Temperature, °F.		1885	1780	1775	1745	1780	1740
Stack Temperature, °F.		645	650	640	695	680	660
Calorific Value of Gas, B.T.U.		96.4	96.7	94.5	83.5	98.0	93.8
Sensible Heat in Gas, B.T.U.		6.2	5.4	5.6	5.8	5.8	5.8
Total Heat in Gas, B.T.U.		102.6	102.1	100.1	89.3	103.8	99.6
Stack Loss per Cu. Ft., B.T.U.		12.3	12.4	12.2	13.2	12.9	12.5
Stack Loss per Cu. Ft. Fce. Gas, B.T.U.		34.2	35.0	36.8	37.6	42.0	39.5
CO Loss per Cu. Ft. Fce. Gas, B.T.U.		7.2	0.9	6.2	0.0	2.1	3.1
Stack Loss, %		33.4	34.4	36.5	42.1	40.5	39.7
CO Loss, %		7.0	7.1	6.2	....	2.0	3.1
Radiation Loss, %		5.0	5.0	5.0	5.0	5.0	5.0
Efficiency, %		54.6	53.5	52.3	52.9	52.5	52.2

OPERATION OF BOILERS WITH COMMON BURNER.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 4.—250 H. P., B. & W. BOILERS.
PRELIMINARY TESTS TO DETERMINE STATE OF COMBUSTION.

Date		1/31 1914	2/2 1914	2/4 1914	2/5 1914	2/6 1914	3/13 1914	3/17 1914	3/28 1914
Boiler No.		14	14	14	14	14	13	17	17
Style of Burner and Fuel		Common Burner			Clean	Gas			
B.H.P. Developed							274	247	257
Per cent of Rating Developed							110	99	103
Furnace Gas Analysis. (Dry)	CO_2	13.2	13.6	13.2	13.4	13.0	13.4	13.6	13.8
	CO	25.0	24.4	25.0	24.8	25.4	24.8	25.6	25.0
	H_2	3.6	3.4	3.6	3.6	3.6	3.4	3.6	3.6
Comb. Chamber Gas Analysis (Dry)	CO_2	21.2	20.3	22.5	16.9	17.5	16.8	18.8	20.1
	O_2	1.4	4.7	2.7	7.5	7.1	0.0	0.4	0.5
	CO	6.1	3.9	0.7	1.0	1.5	10.3	10.8	8.3
3rd. Pass. Analysis (Dry)	CO_2	..	..	..	13.3	..	16.4	16.2	17.6
	O_2	..	..	..	11.0	..	5.9	6.4	4.9
	CO	..	..	..	0.3	..	..	..	..
Stack Gas Analysis (Dry)	CO_2	18.2	12.4	11.9	8.1	9.5	..	..	..
	O_2	6.4	11.0	11.6	14.3	13.9	..	..	..
	CO	0.2	0.1	0.1	0.0	0.0	..	..	..
Ratio { Furnace Gas (Dry) / C. C. Gas (Wet) }		1.45	1.63	1.71	2.22	2.10	1.46	1.38	1.42
Air Excess, 3rd. Pass, %		..	..	..	176.2	..	97.3	106.4	75.4
Ratio { Furnace Gas (Dry) / Stack Gas (Wet) }		2.14	3.13	3.28	4.72	4.04	..	..	..
Air Excess, Stack, %		91	228	245	472	388	..	..	..
Steam Pressure, Lbs.		142	137	136	138	139	146	142	145
Gas Pressure, Ins. H_2O							1.0	1.5	1.5
Feed Water Temperature, °F		169	144	174	185	175	160	153	186
Furnace Gas Temperature, °F		62	62	62	62	62	62	62	62
Combustion Chamber Temperature, °F		1765	1790	1850	1706	1707	1390	1550	1565
Stack Temperature, °F		785	773	603	628	603	505	470	533
Calorific Value of Gas, B.T.U		91.0	88.5	91.0	90.3	92.3	89.8	92.9	91.0
Sensible Heat in Gas, B.T.U.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Heat in Gas, B.T.U.		91.0	88.5	91.0	90.3	92.3	89.8	92.9	91.0
Stack Loss per Cu. Ft., B.T.U.		14.5	14.2	10.8	11.3	10.8			
Stack Loss per Cu. Ft. Fce. Gas, B.T.U.		31.0	44.4	35.4	53.4	43.6			
CO Loss per Cu. Ft. Fce. Gas, B.T.U.		1.4	1.0	1.5	0.0	0.0			
Stack Loss, %		34.1	50.1	38.9	59.1	47.3			
CO Loss, %		1.5	1.1	1.1	0.0	0.0			
Radiation Loss, %		5.0	5.0	5.0	5.0	5.0			
Efficiency, %		59.4	43.8	55.0	35.9	47.7			

OPERATION OF BOILERS WITH COMMON BURNER.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 4—250 H. P., B. & W. BOILERS.
PRELIMINARY TESTS TO DETERMINE STATE OF COMBUSTION.

Date		12/9 1914	12/10 1914	12/11 1914	12/12 1914
Boiler No.		1	1	1	1
Style of Burner and Fuel		Common Burner		Rough Gas	
B.H.P. Developed		318	325	360	371
Per cent. of Rating Developed		127	130	144	148
Furnace Gas Analysis (Dry)	CO_2	12.2	15.7	15.9	15.6
	CO	24.6	24.1	24.5	24.9
	H_2	3.8	3.1	3.5	3.3
Comb. Chamber Gas Analysis (Dry)	CO_2	22.5	23.3	23.8	23.2
	O_2	1.8	0.3	0.1	0.2
	CO	5.5	4.7	5.3	6.8
3rd. Pass Analysis (Dry)	CO_2				
	O_2	Not Taken			
	CO				
Stack Gas Analysis (Dry)	CO_2	15.9	16.5	16.5	16.6
	O_2	8.4	7.2	6.8	6.6
	CO	1.7	1.8	2.3	2.8
Ratio Furnace Gas (Dry) / C. C. Gas (Wet)		1.42	1.53	1.50	1.46
Air Excess, 3rd. Pass., %		..	..	..	..
Ratio Furnace Gas (Dry) / Stack Gas (Wet)		2.28	2.30	2.27	2.21
Air Excess, Stack, %		118.0	100.5	79.5	77.0
Steam Pressure, Lbs.		135	135	135	135
Gas Pressure, Ins., H_2O		..	..	..	..
Feed Water Temperature, °F.		180	180	180	180
Furnace Gas Temperature, °F.		400	425	425	450
Combustion Chamber Temperature, °F.		1791	1783	1791	1820
Stack Temperature, °F.		675	664	665	693
Calorific Value of Gas, B.T.U.		90.3	86.6	88.4	89.8
Sensible Heat in Gas, B.T.U.		6.8	7.3	7.3	7.8
Total Heat in Gas, B.T.U.		97.1	93.9	95.7	97.6
Stack Loss per Cu. Ft., B.T.U.		12.3	12.0	12.1	12.6
Stack Loss per Cu. Ft. Fce. Gas, B.T.U.		28.0	27.6	27.5	26.6
CO Loss per Cu. Ft. Fce. Gas, B.T.U.		13.0	13.4	16.9	20.0
Stack Loss, %		28.8	29.8	28.7	27.6
CO Loss, %		13.4	14.3	17.6	20.5
Radiation Loss, %		5.0	5.0	5.0	5.0
Efficiency, %		52.8	50.9	48.7	46.9

OPERATION OF BOILERS WITH COMMON BURNER.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 4—250 H.P., B. & W. BOILERS.
TESTS TO DETERMINE STATE OF COMBUSTION.

Date		1/1 1915	1/4 1915	1/5 1915	1/6 1915	1/7 1915	1/8 1915
Boiler No.		12	12	12	12	12	12
Style of Burner and Fuel		Common Burner		(Fig. 1).	Clean	Gas	
B.H.P. Developed		388	406	394	390	293	305
Per cent of Rating Developed		155	162	158	156	117	122
Furnace Gas Analysis (Dry)	CO_2	13.4	14.2	14.1	14.4	14.8	14.7
	CO	24.4	24.7	25.4	25.3	24.8	24.5
	H_2	2.9	3.5	3.0	3.2	3.5	3.4
Comb. Chamber Gas Analysis (Dry)	CO_2	21.9	23.0	22.5	20.8	22.0	21.8
	O_2	0.8	0.9	1.4	2.9	0.3	1.0
	CO	5.1	4.1	3.4	2.6	7.7	5.3
3rd Pass Analysis (Dry)	CO_2	..	19.3	17.0	20.6	..	..
	O_2	..	5.0	7.1	4.0	..	..
	CO	..	0.5	0.3	0.6	..	..
Stack Gas Analysis (Dry)	CO_2	18.4	17.9	17.7	17.6	18.8	15.9
	O_2	5.3	6.7	6.2	5.5	4.6	7.6
	CO	1.6	1.0	0.9	2.3	2.8	1.1
Ratio $\left\{\begin{array}{l}\text{Furnace Gas (Dry)}\\\text{C. C. Gas (Wet)}\end{array}\right\}$		1.46	1.49	1.58	1.76	1.39	1.50
Air Excess, 3rd Pass, %		..	66.7	112.7	48.7	..	..
Ratio $\left\{\begin{array}{l}\text{Furnace Gas (Dry)}\\\text{Stack Gas (Wet)}\end{array}\right\}$		1.95	2.12	2.18	2.05	1.89	2.36
Air Excess, Stack, %		62.5	90.2	86.5	60.3	41.5	117.6
Steam Pressure, Lbs.		131	146	135	136	125	125
Gas Pressure, Ins. H_2O		1.4	1.4	1.4	1.4	1.4	1.4
Feed Water Temperature, °F		139	134	124	126	132	142
Furnace Gas Temperature, °F		42	42	43	49	52	48
Combustion Chamber Temperature, °F		1771	1751	1734	1691	1751	1740
Stack Temperature, °F		700	710	715	700	725	718
Calorific Value of Gas, B.T.U		86.0	89.7	91.9	91.8	90.0	87.8
Sensible Heat in Gas, B.T.U		–0.3	–0.3	–0.3	–0.2	–0.1	–0.2
Total Heat in Gas, B.T.U		85.7	89.4	91.6	91.6	89.9	87.6
Stack Loss per Cu. Ft., B.T.U		11.3	13.8	13.9	13.6	14.2	13.9
Stack Loss per Cu. Ft. Fce. Gas, B.T.U		26.5	29.3	30.3	27.9	26.8	32.8
CO Loss per Cu. Ft. Fce. Gas, B.T.U		13.6	6.8	6.3	15.2	17.1	8.4
Stack Loss, %		31.0	32.8	33.0	30.5	29.8	37.4
CO Loss, %		11.7	7.6	6.8	16.6	19.0	9.6
Radiation Loss, %		4.5	4.5	4.5	4.5	4.5	4.5
Efficiency, %		52.8	55.1	55.7	48.4	46.7	48.5

The following condensed results are quoted to show the variations in the different losses and efficiencies:

		Max. Stack Loss. Min. Eff.	Min. Stack Loss. Max. CO Loss.	Max. Eff.
Per Cent. of Ratings Developed		110	112	125
Furnace Gas Analysis:	CO_2%	13.4	13.0	13.2
	CO	24.8	25.5	25.5
	H_2	3.6	3.5	3.6
Comb. Chamber Analysis	CO_2	16.9	19.6	21.2
	O_2	7.5	0.2	1.4
	CO	1.0	8.1	6.1
Stack Gas Analysis	CO_2	8.1	16.1	18.2
	O_2	14.3	5.9	6.4
	CO	0.0	3.5	0.2
Gas Pressure (inches) H_2O		3.5	4.0	3.5
Draft in Furnace (inches) H_2O		.30	.35	.42
Furnace Gas Temperature, degs. F.		60	300	60
Combustion Chamber Temperature, degs. F.		1,706	1,690	1,765
Stack Temperature, degs. F.		628	565	785
Calorific Value of Furnace Gas Cu. Ft. B.T.U.		90.3	92.3	91.0
Sensible Heat of " " " " "		0.0	4.8	0.0
Total Heat of " " " " "		90.3	97.1	91.0
Sensible Heat Lost in Stack, per cent.		59.1	22.2	34.1
Unconsumed CO Lost in Stack, per cent.		0.0	23.8	1.5
Radiation (assumed)		5.0	5.0	5.0
Efficiency, per cent.		35.9	49.0	59.4

The maximum efficiency, as might be expected, occurs with neither a minimum sensible heat loss or CO loss, which is generally the case with high efficiencies. This efficiency of 59.4 per cent. may be considered about the maximum under present conditions and equipment, and indicates that, with the attention to details of operation as discussed above, a continuous operating efficiency of about 58 per cent. is possible at rating up to 175 per cent. of full load. It would seem that this is a very low figure, yet it is safe to say that it is exceeded in but very few blast-furnace boiler plants. The efficiency of the Duquesne Blast Furnace Boilers at the present time is in the vicinity of 55 per cent., the plant furnishing steam in addition to all blast-furnace requirements, electric power and water pumping, at the rate of 2,000 B.H.P. per furnace. Twenty-two plants of the United States Steel Corporation, having a total boiler horse power of 241,504, show an average operating efficiency of 55 per cent.

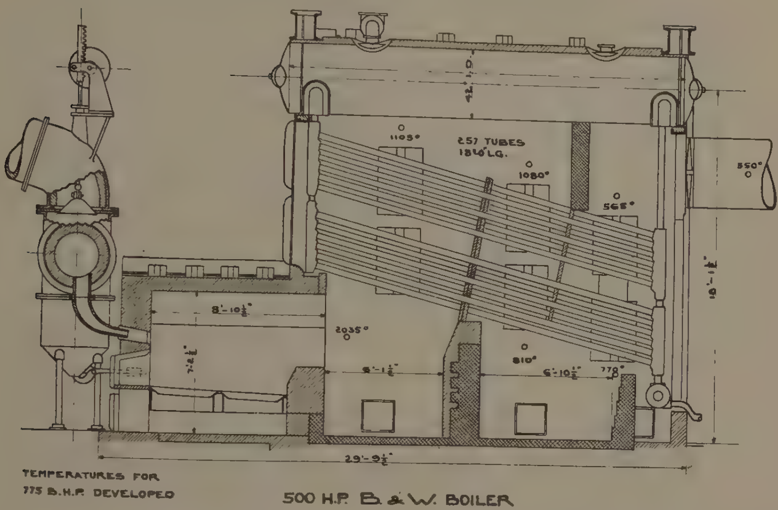


Fig. 9. National Tube Company, McKeesport Works

An example of the high efficiencies that are possible with the old-style burner, coupled with large boilers, long combustion chambers, excellent condition of settings and baffles, sufficient air supply, damper regulation, and close

McKeesport Boiler Setting—Wilson Regulating Valve.

attention is presented in the performance of the 500 H.P., B. & W. Boilers (Fig. 9) at the National Tube Company at McKeesport, Pa. (See cut on page 351.) The observations and calculations at McKeesport were checked by the Experimental Engineering Department of the Duquesne Works, and are shown below:

Per Cent. of Rating Developed			155%
Furnace Gas Analysis	CO_2		13.0
	CO		25.6
	H_2		3.2
Combustion Chamber Analysis	CO_2		24.7
	O_2		0.1
	CO		2.0
Stack Gas Analysis	CO_2		21.2
	O_2		3.7
	CO		0.6
Gas Pressure			....
Draft in Furnace			....
Furnace Gas Temperature			300°F.
Combustion Chamber Temperature			2,040°F.
Stack Temperature			545°F.
Calorific Value of Furnace Gas Per Cu. Ft.		B.T.U.	91.9
Sensible Heat of Furnace Gas Per Cu. Ft.		"	4.8
Total Heat of Furnace Gas Per Cu. Ft.		"	96.7
Sensible Heat Lost in Stack			19.0%
Unconsumed CO Lost in Stack			3.7
Radiation (assumed)			5.0
Efficiency			72.3

The good analyses and high temperature in combustion chamber are attributed to proper air supply and long Dutch Oven, and the good stack analyses and low stack temperature to the excellent condition and attention to the settings and baffles. The average monthly efficiency of the plant, as stated by their engineering department, is 68 per cent. An excellent gas valve, designed by Mr. J. W. Wilson, assists in the gas control.

Type 2—Rectangular or circular burner with air conducted into the gas jet by means of pipes or other openings, and auxiliary ports through which additional air is admitted around the burner nose.

Two forms of the Birkholz-Terbeck burner, which is of this type, are shown in Figs. 10 and 11. The form shown in Fig. 11, which is the simpler of the two, will be discussed, as both are the same in principle. The primary air

is admitted in a nozzle placed in the back of the burner. Gas from the pipe above passes around this nozzle and mixes with the air in the section of pipe following. The

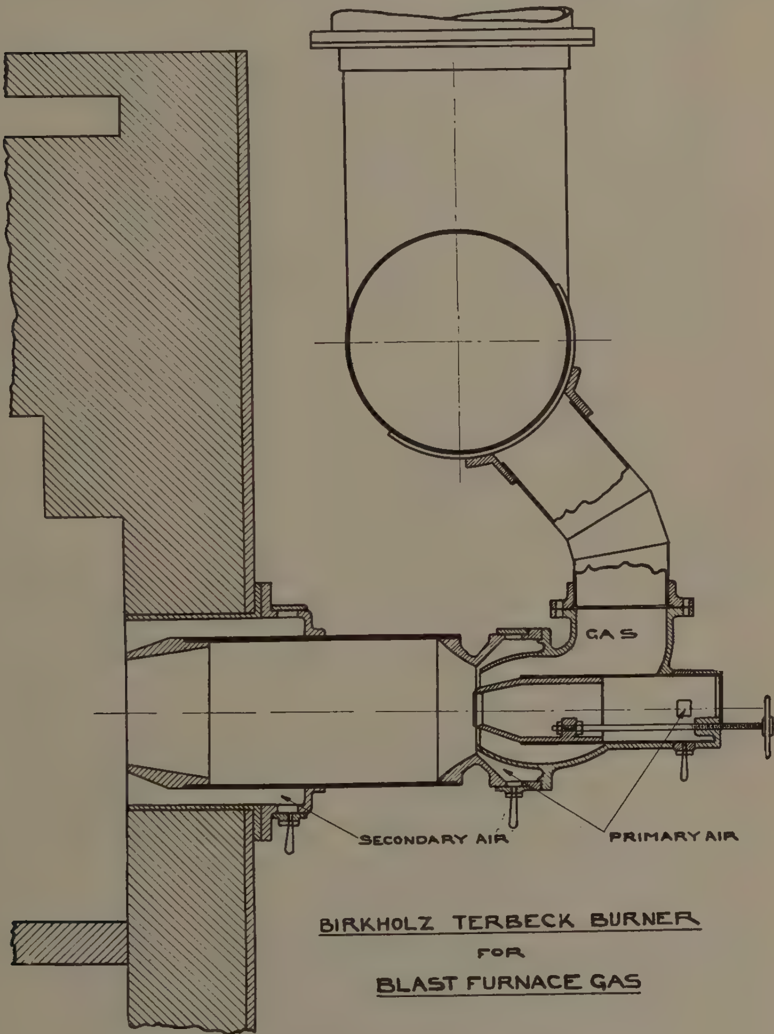


Fig. 10

theory is that the gas, in passing through the throat into the larger area of the mixing chamber, has its pressure reduced and thereby induces flow through the air nozzle

proportional to the flow of gas. That sufficient air cannot be aspirated in this manner is shown by the provision of a secondary inlet at the nose of the burner, which is

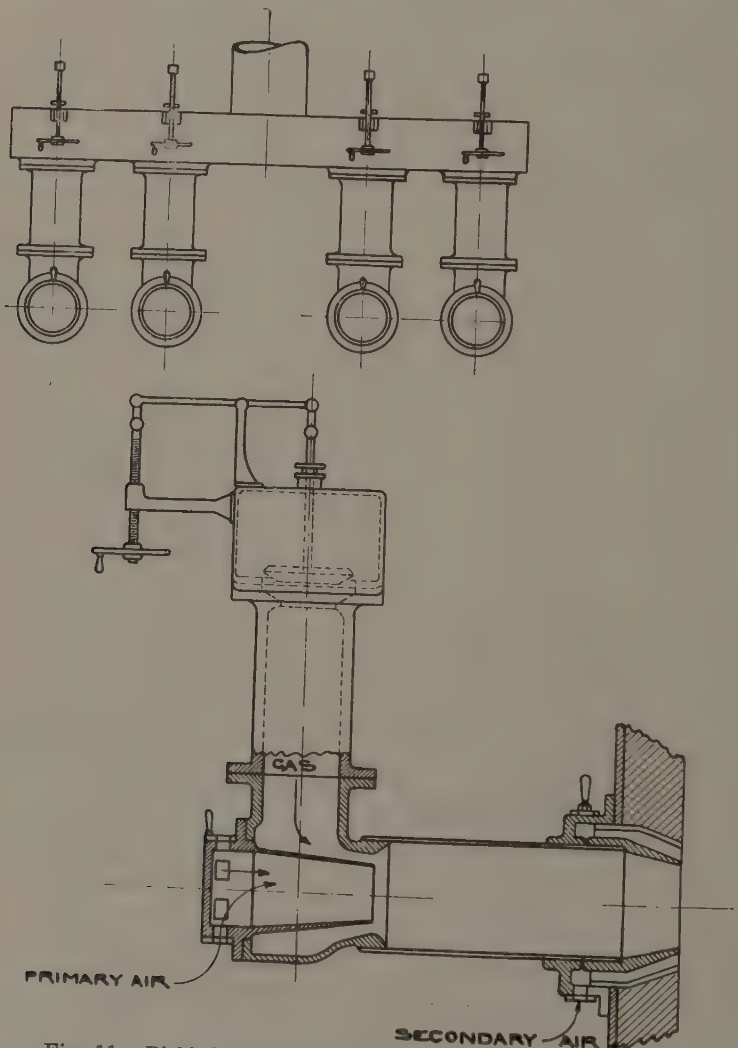


Fig. 11. Birkholz-Terbeck Burner for Blast Furnace Gas

affected by stack draft to the same extent as the space surrounding the nose of a common burner, and which probably supplies as much air as the primary inlet.

Therefore, this portion of the air is not mixed before the ignition point. No record of gas analyses in the combustion chamber or flame temperatures are available from tests of these burners. However, at the South Works of the Illinois Steel Co., comparative tests which were run simultaneously on two 325 H.P. Stirling boilers in the same battery and at the same rating show similar stack analyses and temperatures, and about equal efficiencies for both the Birkholz-Terbeck and the common burners. A large number of tests were run on a 325 H.P. Rust boiler, the one in condensed form following, being representative of the general average:

		Common	*Birkholz-Terbeck*
Per Cent. of Rating Developed		130	130
Furnace Gas Analysis	CO_2%	14.0	14.0
	CO	25.0	25.0
	H_2	3.6	3.6
Combustion Chamber Analysis	CO_2%	....	....
	O_2	....	....
	CO	....	....
Stack Gas Analysis	CO_2%	21.4	22.8
	O_2	3.8	2.8
	CO	0.0	0.3
Gas Pressure		.15	.7
Drafts in Furnace		....	....
Furnace Gas Temperature, degs. F		45	45
Combustion Chamber Temperature, degs. F		....	....
Stack Temperature		872	823
Calorific Value Furnace Gas Cu. Ft. B.T.U.		91.9	91.9
Sensible Heat of Furnace Gas Cu. Ft. B.T.U.		.3	.3
Total Heat of Furnace Gas Cu. Ft. B.T.U.		91.6	91.6
Sensible Heat Lost in Stack		36.6%	32.8%
Unconsumed CO Lost in Stack		0.0	1.8
Radiation (assumed), per cent		5.0	5.0
Efficiency, per cent		58.4	60.9

Tests were also conducted at South Works, on a 355 H.P. Wheeler boiler, which they state is an uneconomical type. Efficiencies around 60 per cent. were obtained and were considered quite gratifying for the installation. The test results closely resemble those given above, an increased efficiency was shown in a comparison of the tests of 15 per cent. The average result obtained in the Wheeler boilers with the former settings showed 45 per cent. In the case of these boilers far greater capacity should be derived from the Birkholz-Terbeck burners, due

to their peculiar adaptation to this type of boiler, than was possible to obtain with any adjustment of the former method.

BACON'S TESTS.

The following description of tests and data sheets form a very complete and extremely valuable addition to the present paper and are inserted not only for purposes of burner comparisons but as representative of blast furnace gas boiler tests under the conditions described, and conducted by one of the most prominent steam engineers of the country, Mr. Charles J. Bacon.

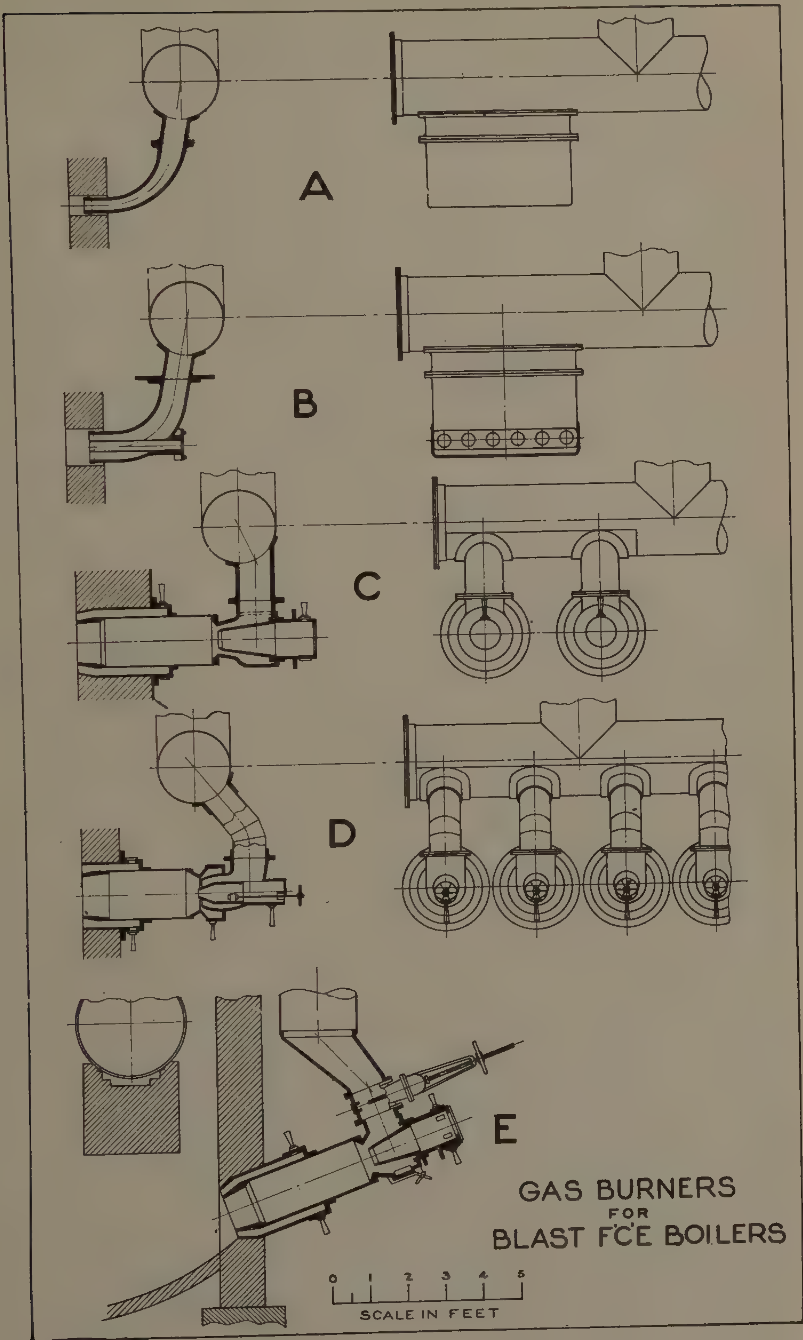
These tests were made to determine the relative performance of five types of blast furnace gas burners as applied to Stirling, Rust and Wheeler boilers. The burners are designated herein as

A. Common type of simple construction, having a narrow orifice at the exit and no provisions for mixture of gas and air within the burner. The air is admitted through the openings in the boiler front around the burners, supplemented with air through the fire and ash doors, if required. On account of the small orifice this burner has the disadvantage of giving a high velocity to the gas.

B. An improved burner, of Bunsen type, the air being admitted through a row of six 4-inch tubes with adjustable openings, serving also for observation purposes. The exit opening, of the rectangular form, is much larger than in A, so as to give a low velocity to the mixture entering the furnace.

C. Known as the "Birkholz" or "Terbeck" burner. Also of Bunsen type, but differs from B in many points of design. Made to accurate dimensions in circular instead of rectangular form, and in addition to an adjustable primary air inlet in the burner proper, it is provided with an adjustable secondary inlet for admitting air to the furnace. A central glass window, through which the flame may be seen, facilitates regulation of the air supply.

D. Another form of "Birkholz" burner, having three adjustable air inlets.


A
B
C
D
E
GAS BURNERS
FOR
BLAST FC'E BOILERS
0 1 2 3 4 5
SCALE IN FEET

E. Similar to C, differing only in details.

In making these tests the specific object was to determine the degree of superiority of the Birkholz burner over types A and B in the normal operation of gas-fired boilers. Some of the tests were made under approximately "test conditions" in order to more closely analyze the peculiarities of the different burners. In other tests attempt was made to obtain data on comparative performance when both burners were operated by the regular boiler attendants. Many of the runs were of only one hour or two in duration. The method of measuring evaporation by steam flow meters instead of weighing feed water eliminated corrections for variations in water level, consequently the effect of varying the operating conditions and making different adjustments on the burners could be investigated in relatively short periods of time. Tests of long duration with the attempt to conform to normal operating conditions as a rule are not satisfactory from an analytical standpoint due to the difficulty of keeping a record of variations in evaporation, gas pressure, etc., but some of the tests closely approximate operating conditions. Prior to all tests the boiler furnaces and settings were put in good condition in order that the value of the results might not be confused by the effects of air leakage.

By consulting the tabulated data it will be seen that the gas consumption and efficiencies were not based by actual measurement of the fuel gas but by what is known as the "indirect test method," namely, a determination of the percentage of stack losses by means of temperatures and analyses of the stack and fuel gases. By making a reasonable allowance of five per cent. for radiation and unaccounted for losses, based on independently conducted heat balance tests, the percentage of heat usefully employed, i. e., the efficiency, was computed by difference. Having thus determined the efficiency, the rate of gas flow per unit of time and per boiler horsepower was readily obtained.

TABLE I

TESTS OF BURNERS "A" AND "C" ON STIRLING BOILERS

With Raw Blast Furnace Gas at Normal Pressure

Test No.	1	2		3		4		5		6		7	
Boiler No.		1	2	1	2	1	2	1	2	1	2	1	2
Burner		C	A	C	A	C	A	C	A	C	A	C	A
Date		10/7/14	10/7/14	10/8/14	10/8/14	10/8/14	10/8/14	10/23/14	10/23/14	10/23/14	10/23/14	10/23/14	10/23/14
Duration of Test	Hours	2.33	2.33	2.00	2.00	183	1.83	1.00	1.00	0.83	0.83	1.67	1.67
Average Pressures:													
Steam at Boiler by Gauge	Lb. Per Sq. In.	143	143	142	142	137	137	136	136	139	139	139	139
Draft Under Damper	In. Water	.77	.82	.76	.79	.76	.80	.90	.86	.90	.86	.90	.85
Draft in Furnace	In. Water												
Gas Pressure in Main	In. Water	14.40	14.40	15.30	15.30	1020	10.20						
Gas Pressure in Boiler Gas Header	In. Water	1.3	–.05	1.90	.25	.60	–.28	.3	.43	.97	.25	.1	.5
Loss of Pressure Through Burner	In. Water	2.1	.59	2.50	.77	130	.48	1.1	.36	1.7	.5	.6	.21
Average Temperatures:													
Fuel Gas in Main	Deg. F.	231	231	224	224	209	209	170	170	193	193	182	182
Feed Water Entering Boiler	Deg. F.	202	202	200	200	202	202	185	185	184	184	180	180
Stack Gases	Deg. F.	725	795	791	859	688	726	661	683	688	731	636	671
Fuel:													
Gas per Hour (Calculated) St'd Conditions	Cu. Ft.	227760	235650	259430	270000	192250	199600	175765	181975	216300	210400	150600	157000
Gas per Boiler Horse-power	Cu. Ft.	520	538	522	543	527	541	453	469	489.5	476	462	481.5
Analysis of Fuel Gas:													
Carbon Dioxide CO_2	%	14.55	14.55	13.95	13.95	14.60	14.60	11	11	10.7	10.7	11.2	11.2
Oxygen O	%	.25	.25	.30	.30	.20	.20	.0	.3	.3	.1	.1	.11
Carbon Monoxide CO	%	25.40	25.40	25.63	25.63	24.88	24.88	26.32	26.32	25.92	25.92	25.78	25.78
Hydrogen H	%	3.05	3.05	3.48	3.48	3.13	4.08	4.08	4.8	4.2	4.2	3.62	3.62
Methane CH_4	%	.17	.17	.11	.11	.21	.21	.42	.42	.52	.52	.74	.74
Calorific Value of Dry Fuel Gas:													
Per Cu. Ft., High Value Standard Conditions	B.T.U.	94.81	94.81	96.32	96.32	93.68	93.68	103.63	103.63	103.65	103.65	102.5	102.5
Per Lb., High Value	B.T.U.	1223.4	1223.4	1258.1	1258.1	1206.2	1206.2	1375.3	1375.3	1381.5	1381.5	1370	1370
Per Cu. Ft., Inc. Sens. and Latent Heat	B.T.U.	105.5	105.5	107.2	107.2	103.6	103.6	112.6	112.6	113.1	113.1	112.4	112.4
Per Lb., Inc. Sens. and Latent Heat	B.T.U.	1356.3	1356.3	1389.1	1339.1	1333.0	1333.0	1491.2	1491.2	1503.8	1503.8	1485	1485
Analysis of Stack Gas:													
Carbon Dioxide CO_2	%	23.20	23.66	23.30	23.20	22.70	21.70	21.83	20.93	22.3	21.6	19.6	18.4
Oxygen O	%	2.96	2.91	2.70	3.10	3.44	4.09	3.43	3.33	2.3	3.1	5.2	6.1
Carbon Monoxide CO	%	.18	.15	.06	.0	.08	.06	.0	.18	1.3	.3	.0	.0
Nitrogen N (By Difference)	%	73.66	73.28	73.94	73.70	73.78	74.15	74.74	75.56	74.1	75.0	75.2	75.5
Water Per Hour:													
Evaporation as Read by Steam Flow Meter	Lb. Per Hr.	14257	14257	16176	16176	12000	12000	12500	12500	14200	14200	10420	10420
Factor of Evaporation		1.060	1.060	1.060	1.060	1.060	1.060	1.072	1.072	1.075	1.075	1.080	1.080
Equiv. Evap. Dry Steam from and at 212°F	Lb. Per Hr.	15110	15110	17150	17150	12720	12720	13405	13405	15260	15260	11255	11255
Horse Power:													
On Basis of 34.5 Lb. from and at 212°F	B.H.P.	438	438	497	497	369	369	388	388	442	442	326	326
Builder's Rating on 10 Sq. Ft. Heating Surface	B.H.P.	360	360	360	360	360	360	360	360	360	360	360	360
Per Cent. Rating Developed	%	1.217	1.217	1.38	1.38	1.025	1.025	1.077	1.077	1.227	1.227	.905	.905
Efficiency:													
Stack Losses (Calculated from Flue Gas Conditions)	%	34.0	36.0	35.1	37.5	32.9	35.2	29.3	31.6	34.5	32.8	30.5	33.1
Radiation and Unaccounted for Losses (Assumed)	%	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Boiler Efficiency (By Difference)	%	61.0	59.0	59.9	57.5	62.1	59.8	65.7	63.4	60.5	62.2	64.5	61.9

Six series of tests were made, as follows:

Table	Tests	Boilers	Burners	Gas Conditions	Regulation.
I	1 to 7	Stirling	A and C	Raw gas at med. press.	By burners.
II	8 to 17	Rust	A and D	Washed gas at low press.	By burners & dampers.
III	18 to 27	Rust	A and D	Washed gas at med. press.	By burners.
IV	28 to 36	Rust	A and D	Washed gas at med. press.	By dampers.
V	37 to 49	Stirling	B and C	Washed gas, normal press.	By burners & dampers.
VI	50 to 53	Wheeler	E	Washed gas, normal press.	By burners.

Tests with Burners A and C on Stirling Boilers—Table I.

The first tests were made on 360 horse-power, Class G-19 Stirling boilers Nos. 1 and 2. These boilers were supplied with raw gas.

No. 1 boiler was fitted up with four Birkholz burners designated herein as type C. This was the first burner of the Birkholz type proposed and had two adjustable air inlets, while the later designs D and E had three air inlets and other changes, particularly in respect to the shape and positions of the gas and air nozzles. No. 1 boiler was equipped with these burners in August, 1914, and therefore had been operating about two months before any systematic tests were attempted. During this period the setting had been repaired where necessary and the boiler put into generally good condition. In making the tests it was desired to obtain data for comparing the Birkholz burner with two existing types designated as A and B, which had been in use in that boiler house for several years. Therefore No. 2 boiler, which is adjacent to No. 1 boiler and provided with a common stack, was fitted up for testing burner A. The intention was to test burners of type B on this boiler after tests of burner A were completed, but this plan was not carried out at this time on account of temporary deficiency of gas supply. (See tests 37 to 49 for later tests with burner C.)

Each boiler was equipped with three thermo-electric pyrometer couples located under the stack damper, one at the middle of the damper opening, and one about one

foot from each side wall. The six couples were connected to a common pyrometer through a multi-point switch. Samples of stack gas for analysis were taken simultaneously from the same points under the damper where the pyrometer couples were located, the gas from these three sampling pipes passed into a common header from which the sample for analysis was drawn. Two Orsats were used, one for each boiler. The evaporation was measured by a General Electric Co. recording steam flow meter connected to two nozzle plugs, one for each boiler. In order to give reliable readings the 8-inch goosenecks between the boilers on the main steam header were removed, and replaced by temporary 6-inch connections so as to give higher steam velocity. The connections between nozzle plugs and the recording flow meter were so arranged that the meter could be changed from one boiler to the other by manipulating some small valves. This method of using flow meter was adopted to eliminate all question as to the relative evaporation of the two boilers. In order to have a check on the accuracy of the flow meter, a 2-inch by 5/8-inch Venturi meter was installed in the feed water connection to No. 1 boiler and readings thereon checked within 3 per cent. of the indications of the flow meter. During the tests the feed water was regulated by hand in order to maintain a uniform flow. The tests were not run over extended periods, as long tests are not necessary when the evaporation is measured with steam flow meters.

In addition to the above observations, readings were taken of pressure in the blast furnace gas main, pressure above the burners, difference in pressure between the furnace and burners, stack draft at the dampers, temperatures of the raw gas and feed water, and pressure of the steam.

Several preliminary tests were made for the purpose of putting both boilers in equally good condition. Considerable difficulty was encountered in finding and stopping air leakage through the settings, as made evident by

taking gas samples and temperatures from different points in the damper openings. In spite of all efforts, including pointing up to the brickwork and painting it with several coats of tar, it was not possible to entirely eliminate the leakage. However, it was practically equalized on the two boilers. While a moderate amount of air leakage may not have a serious effect in the regular operation of boilers, it makes testing particularly difficult, as it is impossible to determine whether excess oxygen shown in the stack gas analysis is due to an excess of air at the burner or to air leakage through boiler setting. Therefore, in order to make comparison of gas burners, it was necessary that the setting leakage be reduced to a minimum. As the dampers in both boilers had been removed by the boiler house operators before starting the tests, the regulation of draft to correspond to load conditions was impossible.

In the tests that followed, both boilers were given more attention than is customary in normal operation, therefore the results may be found of more value technically than practically.

Tests 2, 3 and 4 were made on October 7 and 8, for the purpose of comparing the performance of the two burners at three different loads, 119, 135 and 100 per cent. rating. In each test combustion was made as nearly perfect as possible and it will be seen from Table 1 that the stack analyses were equally good for both types of burners, but the common burner A on No. 2 boiler gave high stack temperatures, which had the effect of slightly increasing the stack losses. In these three tests, the efficiency, calculated by the indirect method, was found to be about two per cent. higher with the Birkholz burners than with the common burners.

Following these tests, one of the two blast furnaces was blown out, resulting in diminishing gas supply. The boilers were then taken off for thorough overhauling and cleaning, so that the tests were not resumed until October 23, when tests 5, 6 and 7 were run.

With variable gas pressure, such as occurs in normal operation, and without regulation of air supply, burners A and C gave practically the same results. In test 5 the burners were adjusted to give nearly perfect combustion at approximately boiler rating. In order to determine the relative action of both burners, the gas pressure in the header above the burner was increased on test 6, resulting in higher stack temperature and an increase in the amount of CO in the stack. A comparison of the stack anaylses indicated that the common burner automatically regulated its air supply at least as well as the Birkholz burner. The stack temperature, however, increased more with burner A than with burner C. Following this, test 7 was run by reducing the gas pressure above all the burners, resulting in elimination of CO in the stack gas, an increase in excess oxygen, and a decrease in stack temperature so that the difference in efficiency still remained about the same for both burners.

The Birkholz burners are equipped with glass windows, enabling the operator to control by the eye, to a certain extent, the quality of the mixture. Although the air supply was not altered during tests 6 and 7, it was evident that the regulation of burner C could have been improved by using the observation window as a guide. It was found when burning dirty gas that, by the adjustment of the air ports so as to give a slightly smoky appearance of the flame at the mouth of the burner, relatively good combustion could be obtained, but obviously the best results were obtainable by analyzing the products of combustion.

TESTS WITH BURNERS A AND D ON RUST BOILERS—TABLE II.

The second series of tests were made on two 325 horse-power Rust boilers No. 33 and 34. These boilers were supplied with washed gas. No. 34 boiler was equipped with four Birkholz burners designated herein as type D shown on drawings 2 and 17759. This type has three adjustable air inlets and is also equipped with a movable nozzle operated by means of a hand wheel and screw. The nozzle slides in a sleeve which conducts the air from the first set of air inlets to the mixing chamber. The purpose of this nozzle is to provide a means of varying the gas nozzle discharge area and thereby the gas velocity.

No. 33 boiler, having two old burners of type A, was fitted up for testing. Both boilers are connected to an economizer from which the gas passes to a concrete stack 175 feet high. Each boiler was equipped with similar testing apparatus as that used in the first series of tests on Stirling boilers. A separate General Electric steam flow meter was provided for each boiler. The piping and valves were arranged such that both steam meters could be connected to either nozzle plug thereby permitting a comparison of the records of the two instruments. As in series I, a Venturi meter was used to check the steam metered.

Preliminary tests were made for the purpose of putting the boilers in equally good condition. With this end in view, the ash pit and firing doors were bricked up, except in No. 33 boiler small openings were left in the doors to permit the addition of more air for combustion than that provided by space around the burner. Stack gas temperatures and analyses were taken as in the first series of tests, and air leakage through the boiler settings reduced to a minimum as shown by stack observations.

Tests 13, 14, 16 and 17 were run under conditions closely approximating those of normal operation. Ad-

TABLE II

TEST OF BURNERS "A" AND

With Washed Blast Furnace

Test No.		
Boiler No.		33
Burner		A
Date		12/11/14
Duration of Test	Hours	2.33
Average Pressures:		
Steam at Boiler by Gauge	Lb. Per Sq. In.	130
Draft Under Damper	In. Water	0.61
Draft in Furnace	In. Water	
Gas Pressure in Main	In. Water	1.30
Gas Pressure in Boiler Gas Header	In. Water	
Loss of Pressure Through Burner	In. Water	
Average Temperatures:		
Fuel Gas in Main	Deg. F.	45.0
Feed Water Entering Boiler	Deg. F.	280
Stack Gases	Deg. F.	867
Fuel:		
Gas Per Hour (Calculated) St'd Conditions	Cu. Ft.	195500
Gas Per Boiler Horse-power	Cu. Ft.	546.5
Analysis of Fuel Gas:		
Carbon Dioxide CO_2	%	9.90
Oxygen O	%	.30
Carbon Monoxide CO	%	26.88
Hydrogen H	%	2.72
Methane CH_4	%	.16
Calorific Value of Dry Fuel Gas:		
Per Cu. Ft., High Value Standard Conditions	B.T.U.	98.5
Per Lb., High Value	B.T.U.	1298.8
Per Lb., Incl. Sens. and Latent Heat	B.T.U.	1307.2
Per Cu. Ft., Inc., Sens. and Latent Heat	B.T.U.	99.4
Analysis of Stack Gas:		
Carbon Dioxide CO_2	%	21.7
Oxygen O	%	2.4
Carbon Monoxide CO	%	0.26
Nitrogen N (By Difference)	%	75.64
Water Per Hour:		
Evaporation as Read by Steam Flow Meter	Lb. Per Hr.	12360
Factor of Evaporation		.974
Equiv. Evap. Dry Steam, from at and at 212° F.	Lb. Per Hr.	12040
Horse Power:		
On Basis of 34.5 Lb. from and at 212° F.	B.H.P.	358
Builder's Rating on 10 Sq. Ft. Heating Surface	B.H.P.	325
Per Cent. Rating Developed	%	110
Efficiency:		
Stack Losses (Calculated from Flue Gas Conditions)	%	33.3
Radiation and Unaccounted for Losses (Assumed)	%	5.0
Boiler Efficiency (By Difference)	%	61.7

"D" ON RUST BOILERS

Gas at Low Pressure

13	14		16		17	
34	33	34	33	34	33	34
D	A	D	A	D	A	D
12/11/14	12/11/14	12/12/14	12/19/14	12/19/14	12/29 to 30/14	12/29 to 30/14
2.33	3.00	3.00	2.00	2.00	30.00	30.00
130	125	125	125	125	135	135
0.73	0.61	0.72			0.71	0.70
1.30	1.00	1.00	1.5	1.5	0.90	0.90
		0.60		1.25		
45.0	45.0	45.0	47	47	45	45
280	275	275	320	320	275	275
771	848	741	891	755	847	762
181800	176000	182800	172500	161750	176400	151000
527	552	586	560	584	543	572.5
9.90	10.2	10.2	10.2	10.2	10.0	10.0
.30	.8	.8	.8	.8	0.1	0.1
26.88	26.8	26.8	26.8	26.8	26.4	26.4
2.72	2.2	2.2	2.2	2.2	3.6	3.6
.16	.2	.2	.2	.2	.45	.45
98.5	96.8	96.8	96.8	96.8	102.6	102.6
1298.8	1274.1	1274.1	1274.1	1274.1	1368.2	1368.2
1307.2	1282.5	1282.5	1282.5	1282.5	1376.6	1376.6
99.4	98.1	98.1	98.1	98.1	103.7	103.7
20.4	20.7	17.3	21.5	15.9	20.3	15.4
3.9	3.8	5.2	3.0	7.8	3.8	8.0
0.2	0.0	0.6	0.1	0.0	0.6	0.3
75.5	75.5	76.9	75.4	76.3	75.3	76.3
11920	11000	10770	10610	9565	11420	9278
.974	.978	.978	.932	.932	.980	.980
11600	10750	10525	9880	8920	11200	9090
345	319	312	308	277	325	264
325	325	325	325	325	325	325
106.2	98.2	96	94.8	85.2	100	81.1
31.0	33.1	36.7	34.0	36.5	35.5	38.3
5.0	5.0	5.0	5.0	5.0	5.0	5.0
64	61.9	58.3	61.0	58.5	59.5	56.7

justments were made on the burners both as a result of gas analyses and by observing the appearance of the flame in the furnace. Eight labor shifts were made, one man from the engineering department on each shift, who took continuous stack gas samples over one hour periods at the same time taking stack temperatures every 15 minutes. The flow meters in the meantime were giving a continuous record of evaporation. As conditions changed, adjustments were made on the burners of both boilers by observing furnace conditions and by results of gas analysis at the end of each hour.

The stack gas analysis taken on burner A showed equally as good combustion as the analysis from burner D. However, the average stack temperature with burner D averaged 100 degrees lower than with burner A. The greatest difference in stack temperature generally occurred during tests with low gas pressure, which would indicate stratification on the furnace gases with consequent combustion in the boiler passes.

The addition of the second set of primary air ports of burner D as compared to burner C is not warranted by the test results. Equally good results could be obtained with burner C, which is of simple construction and more easily regulated.

TABLE III
TESTS OF BURNERS "A" AND "D" ON RUST BOILERS
With Washed Blast Furnace Gas at Medium Pressure
Burner Regulation

Test No.		18		19		20		21		22	
Boiler No.		33	34	33	34	33	34	33	34	33	34
Burner		A	D	A	D	A	D	A	D	A	D
Date		2/24/15	2/24/15	2/24/15	2/24/15	2/25/15	2/25/15	2/25/15	2/25/15	2/26/15	2/26/15
Duration of Test	Hours	3.00	3.00	2.00	2.00	1.92	1.92	1.50	1.50	1.67	1.67
Average Pressures:											
Steam at Boiler by Guage	Lb. Per Sq. In.	130	130	125	125	130	130	135	135	120	120
Draft Under Damper	In. Water	0.815	0.69	0.83	0.64	0.853	0.80	0.89	0.887	0.937	0.871
Draft in Furnace	In. Water										
Gas Pressure in Main	In. Water	3.5	3.5	3.5	3.5	3.9	3.9	3.5	3.5	1.5	1.5
Gas Pressure in Boiler Gas Header	In. Water	0.3	1.4	0.8	2.5	0.15	0.7	0.2	1.5	–0.1	0.8
Loss of Pressure Through Burner	In. Water										
Average Temperatures:											
Fuel Gas in Main	Deg. F.	45	45	45	45	45	45	45	45	45	45
Feed Water Entering Boiler	Deg. F.	275	275	260	260	285	285	275	275	238	238
Stack Gases	Deg. F.	898	881	946	925	872	823	900	898	809	812
Fuel:											
Gas Per Hour (Calculated) St'd Conditions	Cu. Ft.	241600	215400	267700	239800	208600	183200	227300	215800	212800	209500
Gas Per Boiler Horse Power	Cu. Ft.	627.5	590.5	636.0	605.5	598.0	576.0	618.0	586.5	652.5	631.0
Analysis of Fuel Gas:											
Carbon Dioxide CO_2	%	13.2	13.2	13.8	13.8	14.0	14.0	14.0	14.0	12.6	12.6
Oxygen O	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Monoxide CO	%	24.8	24.8	24.8	24.8	25.0	25.0	25.0	25.0	23.8	23.8
Hydrogen H	%	3.0	3.0	3.2	3.2	3.6	3.6	3.6	3.6	2.0	2.0
Methane CH_4	%	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2
Calorific Value of Dry Fuel Gas:											
Per Cu. Ft., High Value Standard Conditions	B.T.U.	93.0	93.0	93.6	93.6	94.5	94.5	94.5	94.5	86.4	86.4
Per Lb., High Value	B.T.U.	1208.1	1208.1	1213.7	1213.7	1229.7	1229.7	1229.7	1229.7	1117.7	1117.7
Per Cu. Ft., Incl. Sens. and Latent Heat	B.T.U.	93.8	93.8	94.4	94.4	95.45	95.45	95.45	95.45	87.3	87.3
Per Lb., Inc. Sents. and Latent Heat	B.T.U.	1216.3	1216.3	1221.8	1221.8	1237.9	1237.9	1237.9	1237.9	1125.8	1125.8
Analysis of Stack Gas:											
Carbon Dioxide CO_2	%	21.6	22.8	22.6	23.7	21.4	22.8	21.2	23.1	21.1	21.3
Oxygen O	%	2.9	2.6	2.6	2.0	3.8	2.8	3.4	2.5	3.1	3.3
Carbon Monoxide CO	%	0.3	0.0	0.3	0.2	0.0	0.3	0.1	0.0	0.4	0.1
Nitrogen N (By Difference)	%	75.2	74.6	74.5	74.1	74.8	74.1	75.3	74.4	75.3	75.3
Water Per Hour:											
Evaporation as Read by Steam Flow Meter	Lb. Per Hr.	13560	12870	14600	13740	12410	11330	12975	12975	11060	11260
Factor of Evaporation		0.979	0.979	0.994	0.994	0.969	0.969	0.98	0.98	1.016	1.016
Equv. Evap. Dry Steam. from and at 212°F	Lb. Per Hr.	13270	12600	14510	13660	12030	10980	12710	12710	11230	11440
Horse Power:											
On Basis of 34.5 Lb. from and at 212° F	B.H.P.	385	365	421	396	349	318	368	368	326	332
Builder's Rating on 10 Sq. Ft. Heating Surface	B.H.P.	325	325	325	325	325	325	325	325	325	325
Per Cent. Rating Developed	%	118.5	112.4	129.6	121.9	107.4	97.8	113.2	113.2	100.3	102.2
Efficiency:											
Stack Losses (Calculated from Flue Gas Conditions)	%	38.1	34.5	39.2	36.4	36.4	34.1	38.2	35.2	36.2	34.2
Radiation and Unaccounted for Losses (Assumed)	%	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Boiler Efficiency (By Difference)	%	56.9	60.5	55.8	58.6	58.6	60.9	56.8	59.8	58.8	60.8

Test No.		23		24		25		26		27	
Boiler No.		33	34	33	34	33	34	33	34	33	34
Burner		A	D	A	D	A	D	A	D	A	D
Date		2/26/15	2/26/15	2/26/15	2/26/15	3/2/15	3/2/15	3/2/15	3/2/15	3/2/15	3/2/15
Duration of Test	Hours	1.17	1.17	1.25	1.25	1.50	1.50	2.00	2.00	1.00	1.00
Average Pressures:											
Steam at Boiler by Guage	Lb. Per Sq. In.	120	120	120	120	138	138	138	138	137	137
Draft Under Damper	In. Water	0.89	0.725	0.91	0.74	0.86	0.81	0.86	0.78	0.89	0.80
Draft in Furnace	In. Water										
Gas Pressure in Main	In. Water	3.3	3.3	3.5	3.5	4.4	4.4	3.5	3.5	4.0	4.0
Gas Pressure in Boiler Gas Header	In. Water	0.8	2.4	0.7	2.2	0.2	1.5	0.7	2.2	–0.1	0.7
Loss of Pressure Through Burner	In. Water										
Average Temperatures:											
Fuel Gas in Main	Deg. F.	45	45	45	45	45	45	45	45	45	45
Feed Water Entering Boiler	Deg. F.	240	240	278	278	245	245	240	240	288	288
Stack Gases	Deg. F.	978	928	978	951	876	861	941	890	820	796
Fuel:											
Gas Per Hour (Calculated) St'd Conditions	Cu. Ft.	270800	227200	265800	237800	203900	202700	265900	230900	174800	163350
Gas Per Boiler Horse Power	Cu. Ft.	643.0	588.7	637.2	593.0	601.0	598.0	692.5	617.5	664.4	672.5
Analysis of Fuel Gas:											
Carbon Dioxide CO_2	%	12.0	12.0	12.0	12.0	11.5	11.5	13.0	13.0	13.5	13.5
Oxygen O	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Monoxide CO	%	25.6	25.6	25.8	25.8	24.4	24.4	25.0	25.0	24.2	24.2
Hydrogen H	%	3.0	3.0	2.8	2.8	3.2	3.2	2.6	2.6	2.4	2.4
Methane CH_4	%	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2
Calorific Value of Dry Fuel Gas:											
Per Cu. Ft., High Value Standard Conditions	B.T.U.	95.6	95.6	95.56	95.56	91.3	91.3	91.3	91.3	89.04	89.04
Per Lb., High Value	B.T.U.	1249.1	1249.1	1242.7	1242.7	1195.2	1195.2	1190.0	1190.0	1146.1	1146.1
Per Cu. Ft., Incl. Sens. and Latent Heat	B.T.U.	96.45	96.45	96.1	96.1	91.8	91.8	92.7	92.7	89.6	89.6
Per Lb., Inc. Sents. and Latent Heat	B.T.U.	1257.4	1257.4	1250.9	1250.9	1203.5	1203.5	11 98.1	1198.1	1154.2	1154.2
Analysis of Stack Gas:											
Carbon Dioxide CO_2	%	21.5	22.7	21.1	22.6	21.9	21.8	23.3	23.3	18.7	17.7
Oxygen O	%	2.6	2.4	3.0	2.6	3.5	3.5	1.2	2.8	6.2	7.0
Carbon Monoxide CO	%	0.5	0.2	0.2	0.0	0.0	0.0	0.45	0.2	0.0	0.0
Nitrogen N (By Difference)	%	75.4	74.7	75.7	74.8	74.6	74.7	74.05	74.7	75.1	75.3
Water Per Hour:											
Evaporation as Read by Steam Flow Meter	Lb. Per Hr.	14320	13130	14740	14190	11590	11590	12960	12720	9390	8695
Factor of Evaporation		1.014	1.014	0.975	0.975	1.011	1.011	1.015	1.015	0.966	0.966
Equv. Evap. Dry Steam. from and at 212°F	Lb. Per Hr.	14520	13310	14370	13830	11710	11710	13160	12910	9070	8400
Horse Power:											
On Basis of 34.5 Lb. from and at 212° F	B.H.P.	421	386	417	401	339	339	381	374	263	243
Builder's Rating on 10 Sq. Ft. Heating Surface	B.H.P.	325	325	325	325	325	325	325	325	325	325
Per Cent. Rating Developed	%	129.6	118.8	128.3	123.4	104.3	104.3	117.2	115.1	80.9	74.8
Efficiency:											
Stack Losses (Calculated from Flue Gas Conditions)	%	41.0	36.0	40.3	36.2	34.3	34.0	42.8	36.5	38.7	39.4
Radiation and Unaccounted for Losses (Assumed)	%	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Boiler Efficiency (By Difference)	%	54.0	59.0	54.7	58.8	60.7	61.0	52.2	58.5	56.3	55.6

Tests with Burners A and D on Rust Boilers—Tables III and IV.

The third and fourth series of tests, 18 to 36, inclusive, were made on the same Rust boilers from February 24 to March 2, 1915. After conducting the tests in December, 1914, at this boiler house, the gas pressure had increased sufficiently to permit operating the test boilers at greater loads.

In conducting these tests, the methods of obtaining the results were the same as in all the previous tests. Before starting, the same precautions were taken to reduce boiler setting air leakage to a minimum. It was decided to operate the boilers by two distinct methods of controlling the air supply in obtaining the load efficiency curves: (a) by regulating the burners,—tests 18 to 27, curve sheet 2, and (b) by regulating the damper, tests 28 to 36, curve sheet 3.

During tests 18 to 27 inclusive, the dampers were wide open on both boilers and the proper amount of air for combustion, as determined by stack gas analysis, was regulated at the burners. In obtaining the load curve as shown by curve sheet 2 the gas pressure in the boiler gas headers on both boilers was maintained as nearly constant as possible after once establishing the desired load. This was accomplished by hand operation of the gas valves in the down-comers to each header.

During tests 28 to 36, inclusive, the dampers were regulated by hand, thereby controlling the amount of air induced by the stack draft through and around the burners of the two boilers. The gas pressure was regulated as in tests 18 to 27. Both boilers were supplied with as much gas as could be efficiently burned with the dampers wide open, the air ports on both types of burners being adjusted to give the required amount of air. Having established this maximum as a starting point on the load curve, curve sheet 3, the other points were obtained by

TABLE IV

TESTS OF BURNERS "A" AND "D"

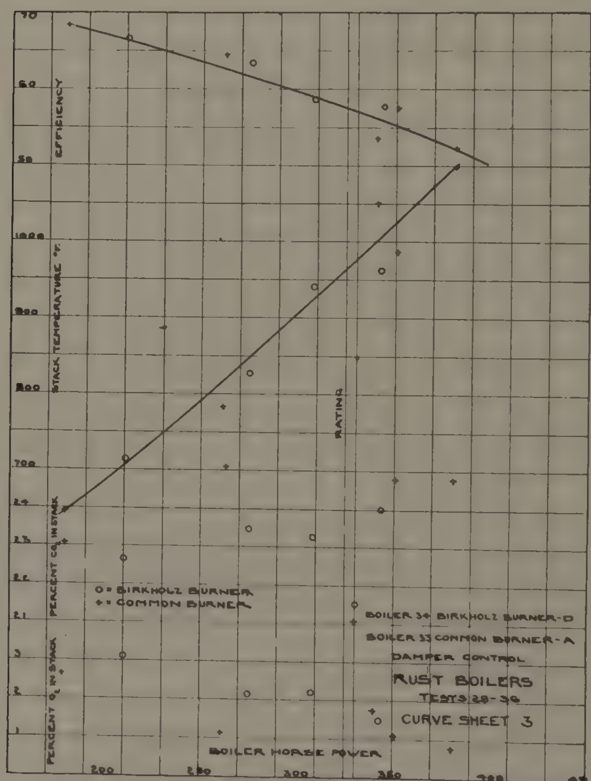
		With Washed Blast Furnace Gas at Damper Regulation	
Test No.		28	29
Boiler No.		34	34
Burner		D	D
Date		3/16/15	3/16/15
Duration of Test	Hours	1.00	1.00
Average Pressures:			
Steam at Boiler by Guage	Lb. Per Sq. In.	134	131
Draft Under Damper	In. Water	.56	.41
Draft in Furnace	In. Water	.11	.08
Gas Pressure in Main	In. Water	4.2	4.8
Gas Pressure in Boiler Gas Header	In. Water	3	2
Loss of Pressure Through Burner	In. Water	3.11	2.08
Average Temperatures:			
Fuel Gas in Main	Deg. F.	45	45
Feed Water Entering Boiler	Deg. F.	277	275
Stack Gases	Deg. F.	961	940
Fuel:			
Gas Per Hour (Calculated) St'd Conditions	Cu. Ft.	223000	196800
Gas Per Boiler Horse Power	Cu. Ft.	650.5	639.0
Analysis of Fuel Gas:			
Carbon Dioxide CO_2	%	12.8	12.8
Oxygen O	%	0.0	0.0
Carbon Monoxide CO	%	23.6	23.6
Hydrogen H	%	3.2	3.2
Methane CH_4	%	0.1	0.1
Nitrogen N	%	60.3	60.3
Calorific Value of Dry Fuel Gas:			
Per Cu. Ft., High Value Standard Conditions	B.T.U.	88.7	88.7
Per Lb., High Value	B.T.U.	1152.6	1152.6
Per Cu. Ft., Inc. Sens. and Latent Heat	B.T.U.	89.4	89.4
Per Lb., Inc. Sens. and Latent Heat	B.T.U.	1160.8	1160.8
Analysis of Stack Gas:			
Carbon Dioxide CO_2	%	24.03	23.26
Oxygen O	%	1.46	2.26
Carbon Monoxide CO	%	.26	
Nitrogen N (By Difference)	%	74.25	74.48
Water Per Hour:			
Evaporation as Read by Steam Flow Meter	Lb. Per Hr.	12100	10860
Factor of Evaporation		.978	.979
Equiv. Evap. Dry Steam, from and at 212° F	Lb. Per Hr.	11830	10630
Horse Power:			
On Basis of 34.5 Lb. from and at 212° F	B.H.P.	343	308
Builder's Rating on 10 Sq. Ft. Heating Surface	B.H.P.	325	325
Per Cent. Rating Developed	%	105.5	94.8
Efficiency:			
Stack Losses (Calculated from Flue Gas Conditions)	%	37.4	36.4
Radiation and Unaccounted for Losses (Assumed)	%	5.0	5.0
Boiler Efficiency (By Difference)	%	57.6	58.6

ON RUST BOILERS

Medium Pressure

30	31	32	33	34	35	36
34	34	33	33	33	33	33
D	D	A	A	A	A	A
3/16/15	3/16/15	3/17/15	3/17/15	3/17/15	3/17/15	3/19/15
1.00	1.00	1.00	1.00	1.00	1.00	1.00
137	138	134	135	135	134	136
.227	.093	.868	.574	.195	.087	.85
.06	.04	.223	.162	.099	.072	.21
5.3	4.0	4.9	5.2	6.0	6.0	3.7
1	.5	1.4	.9	.3	.1	.8
1.06	.54	1.62	1.05	.399	.172	1.01
45	45	45	45	45	45	45
276	273	275	277	281	275	288
825	714	1101	998	782	648	1050
163400	118100	272800	229200	151600	96900	241600
592.5	562.5	716.0	652.5	580.5	540.5	709.5
12.8	12.8	13.2	13.2	13.2	13.2	14.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.6	23.6	23.6	23.6	23.6	23.6	22.4
3.2	3.2	3.2	3.2	3.2	3.2	3.8
0.1	0.1	.1	.1	.1	.1	.1
60.3	60.3	59.9	59.9	59.9	59.9	59.7
88.7	88.7	88.7	88.7	88.7	88.7	86.74
1152.6	1152.6	1152.6	1152.6	1152.6	1152.6	1128.54
89.4	89.4	89.4	89.4	89.4	89.4	87.5
1160.8	1160.8	1160.8	1160.8	1160.8	1160.8	1136.7
23.46	22.66	24.775	24.8	25.1	23.075	23.95
2.13	3.1	.775	1.125	1.15	2.65	1.75
		.475	.15	.375		0.0
74.41	74.24	73.975	73.925	73.375	74.275	74.3
9720	7375	13425	12380	9250	6295	12173
.979	.982	.980	.978	.974	.982	.966
9510	7240	13150	12100	9010	6180	11750
275.7	210	381	351	261	179.2	340.5
325	325	325	325	325	325	325
84.8	64.6	117.2	108.0	80.3	55.2	104.7
31.8	28.4	42.67	37.6	30.5	25.7	41.06
5.0	5.0	5.0	5.0	5.0	5.0	5.0
63.2	66.6	52.33	57.4	64.5	69.3	53.94

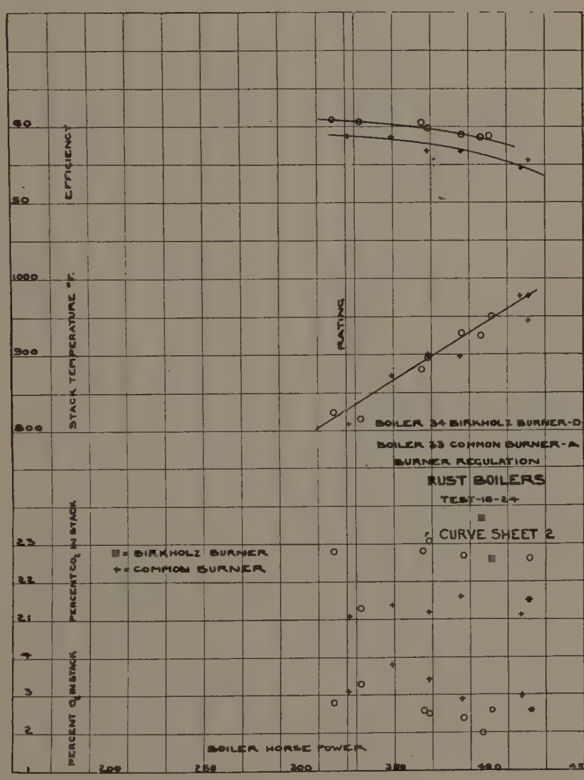
reducing the gas pressure, but instead of adjusting the air ports at the burners as in tests 18 to 27, inclusive, the dampers were closed until stack analysis indicated good combustion. It will be noted by comparing curve sheets 2 and 3, which are plotted to the same scale, that when



operating with damper control, the boiler efficiency was about the same on both boilers, while with burner regulation of the air, the Birkholz burner D shows about two per cent. higher efficiency.

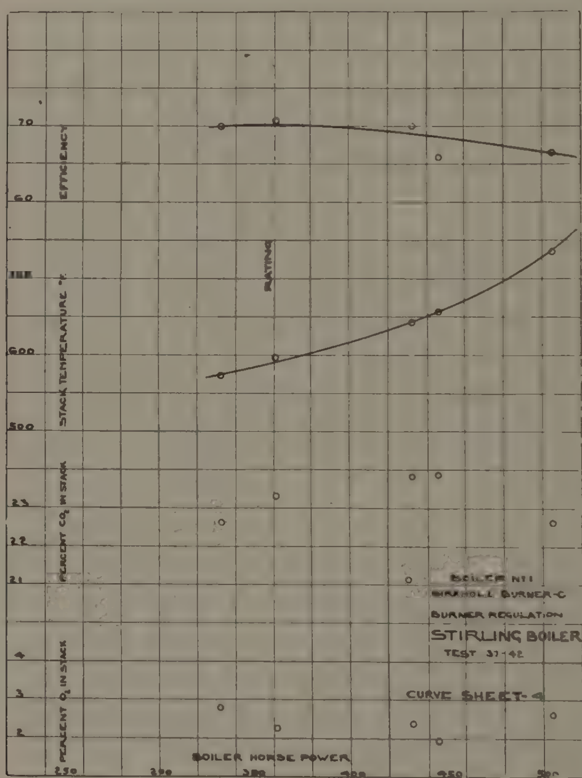
These tests also made it evident that it was extremely difficult to make reliable adjustment of the burners when judged solely by the appearance of the flame. The pres-

ence of moisture and dust gave deceptive effect, moreover it was shown that the best combustion was accompanied by a slightly smoky appearance of the flame, as seen through the glass observation windows, rather than by the bluish-white color usually supposed to indicate



perfect combustion. Some special tests demonstrated that the aspirating effect of Birkholz burner D could not be depended upon to supply the proper amount of air for combustion under varying conditions of gas supply and stack draft. The exercise of considerable manual adjustment by experienced attendants was necessary to accomplish lasting improvement. The mechanical de-

vices of the Birkholz burner facilitated such adjustment, but the burner would not give uniformly good results when left unattended. In comparing the data from these tests it should not be overlooked that the settings and



furnaces of boilers with both types of burners had greater effect in improving the combustion and efficiency than the particular type of burner used.

TABLE V

TESTS OF BURNERS "B" AND "C" ON STIRLING BOILERS

With Washed Blast Furnace Gas at Normal Pressure

Test No.		37	38	39	40	41	42	43	44		45		46		47		48		49	
Boiler No.		1	1	1	1	1	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Burner		C	C	C	C	C	C	B	C	B	C	B	C	B	C	B	C	B	C	B
Date		5/31/15	5/31/15	6/1/15	6/1/15	6/1/15	6/2/15	6/3/15	6/3/15	6/3/15	6/4/15	6/4/15	6/4/15	6/4/15	6/12/15	6/12/15	6/12/15	6/12/15	6/12/15	6/12/15
Duration of Test	Hours	1.83	1.00	1.00	1.00	1.50	1.00	2.00	1.00	1.00	1.67	1.67	2.00	2.00	0.67	0.67	[illegible]	1.00	0.67	0.67
Average Pressures:																				
Steam at Boiler by Gauge	Lb. Per Sq. In.	135	136	133	134	132	136	137	138	138	138	138	138	138	139	139	137	137	130	130
Draft Under Damper	In Water	-.770	-.780	-.800	-.078	-.610	-.780	-.883	-.880	-.850	-.815	-.877	-.776	-.804	-.89	-.89	-.885	-.975	.94	-.965
Draft in Furnace	In Water		-.6			-.55	-.50	-.51	-.50	-.50	-.74	-.725	-.70	-.66	.70	-.79	-.75	-.766	-.87	-.58
Gas Pressure in Main	In Water	9.9	10.85	9.6	9.1	9.7	9.6	8.8	9.0	9.0	10.7	10.7	10.0	10.0	11.60	11.60	11.[illegible]	11.1	10.75	10.75
Gas Pressure in Boiler Gas Header	In Water	1.20	0.75	0.35	0.10	0.35	1.20	-0.34	.75	-0.35	0.15	-0.67	-0.25	-.734	-.315	+.30	-.418	0.0	-.657	+1.40
Loss of Pressure Through Burner	In Water																			
Average Temperatures:																				
Fuel Gas in Main	Deg. F.	88	85	93	90	87	87	86	86	86	86	86	86	86	92	92	92	92	92	92
Feed Water Entering Boiler	Deg. F.	195	185	190	195	190	193	195	203	203	195	195	198	198	201.0	201.0	201.0	201.0	192	193
Stack Gases	Deg. F.	656	642	598	571	625	734	714	721	709	684	648	579	549	783	784	746	752	833	644
Furnace	Deg. F.			2020	1880	1905	1865	1905			2105	2015	1925	1742						
Fuel:																				
Gas Per Hour (Calculated St'd Conditions)	Cu. Ft.	231000	207000	168400	159200	167100	247000	230500	190800	204100	185200	177200	129200	118600	189700	216800	[illegible]	187600	210200	135200
Gas Per Boiler Horse Power	Cu. Ft.	518	478.5	466	479.5	470	489	518.5	492	499	529	541	521	499.5	565	552	562	542	594	521
Analysis of Fuel Gas:																				
Carbon Dioxide CO_2	%	13.4	13.6	12.0	12.2	12.6	12.0	11.0	11.0	11.0	14.2	14.2	14.2	14.2	13.5	13.5	13.5	13.5	13.5	13.5
Oxygen O	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	0.0	0.0	0.0
Carbon Monoxide CO	%	26.6	27.4	27.0	26.8	27.0	27.6	27.2	27.2	27.2	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8
Hydrogen H	%	2.2	2.2	2.4	2.2	3.0	2.4	2.6	2.6	2.6	2.2	2.2	2.2	2.2	2.0	2.0	2.0	2.0	2.0	2.0
Methane CH_4	%	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nitrogen H (By Difference)	%	57.6	56.6	58.4	58.6	57.2	57.8	59.0	59.0	59.0	57.6	57.6	57.6	57.6	58.5	58.5	58.5	58.5	58.5	58.5
Calorific Value of Dry Fuel Gas:																				
Per Cu. Ft., High Value Standard Conditions	B.T.U.	96.17	98.81	98.18	96.81	100.15	100.7	99.44	99.44	99.44	93.57	93.57	93.57	93.57	93.2	93.2	93.2	93.2	93.2	
Per Lb., High Value	B.T.U.	1229.3	1271.8	1294.3	1255.8	1298.55	1304.3	1291.1	1291.1	1291.1	1201.80	1201.80	1201.80	1201.80	1198.7	1198.7	1198.7	1198.7	1198.7	1198.7
Per Cu. Ft., Inc. Sens. and Latent Heat	B.T.U.	98.4	101.6	101.8	100.1	102.6	103.2	101.5	101.5	101.5	96.5	96.5	96.5	96.5	96.6	96.6	96.6	96.6	96.6	96.6
Per Lb., Inc. Sens. and Latent Heat	B.T.U.	1265.79	1304.63	1338.42	1295.14	1334.18	1339.88	1325.67	1325.67	1325.67	1235.74	1235.74	1235.74	1235.74	1240.5	1240.5	1240.5	1240.5	1240.5	1240.5
Analysis of Stack Gas:																				
Carbon Dioxide CO_2	%	23.74	23.8	23.3	22.6	21.9	22.65	21.25	22.3	22.6	22.4	20.54	21.400	19.93	21.8	23.1	20.7	23.4	24.6	21.0
Oxygen O	%	1.94	2.4	2.25	2.8	3.8	2.60	3.32	3.06	3.0	3.0	3.72	3.620	4.65	4.0	2.9	4.7	2.8	.9	4.6
Carbon Monoxide CO	%	0.74	0.0	0.15	0.45	0.0	0.00	0.62	0.00	0.4	0.1	0.30	0.562	0.00	0.0	0.0	0.0	0.1	.9	0.0
Nitrogen N (By Difference)	%	73.58	73.8	74.30	74.15	74.3	74.75	74.81	74.64	74.00	74.5	75.44	74.418	75.42	74.2	74.0	74.6	73.7	73.6	74.4
Water Per Hour:																				
Evaporation as Read by Steam Flow Meter	Lb. Per Hr.	14470	13920	11650	10775	11480	16350	14440	12700	13380	11380	10640	8080	7735	10960	12817	10086	12180	11477	8460
Factor of Evaporation		1.062	1.072	1.068	1.062	1.068	1.065	1.062	1.054	1.054	1.062	1.062	1.06	1.06	1.057	1.057	1.057	1.057	1.063	1.063
Equiv. Evap. Dry Steam, from and at 212. F	Lb. Per Hr.	15370	14920	12450	11450	12265	17410	15340	13380	14110	12085	11300	8560	8200	11580	13540	10670	11930	12210	8995
Horse Power:																				
On Basis of 34.5 Lb. from and at 212° F	B.H.P.	446	432.5	361	332	355.5	505	444.5	388	409	350	327.5	248	237.5	335.8	392.7	309.3	346.0	354.0	259.5
Builder's Rating on 10 Sq. Ft. Heating Surface	B.H.P.	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360
Per Cent. Rating Developed	%	1.24	1.202	1.003	.922	.988	1.403	1.235	1.078	1.132	.972	.91	.689	.66	93.3	109.2	85.9	96.1	98.4	72.1
Efficiency:																				
Stack Losses (Calculated from Flue Gas Conditions)	%	29.3	25.0	24.4	25.2	25.5	28.6	31.4	27.9	28.9	29.3	30.85	28.4	25.5	33.55	32.15	33.3	31.1	36.60	28.45
Radiation and Unaccounted for Losses (Assumed)	%	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Boiler Efficiency (By Difference)	%	65.7	70.0	70.6	69.8	69.5	66.4	63.6	67.1	66.1	65.7	64.15	66.6	69.5	61.45	62.85	61.7	63.9	58.40	66.55

TESTS WITH BURNERS B AND C ON STIRLING BOILERS—TABLE V.

The fifth series of tests was made with washed gas on the same 360 horse-power Stirling boilers as were tests shown on Table I. No. 1 boiler was fitted with burner C and No. 2 boiler with burner B.

Before starting the tests the boiler settings were put in as good condition as possible. All air leaks that could be detected were stopped and both boilers were painted with a mixture of tar and asbestos cement. Both boilers then showed about the same air leakage. The same method of testing and apparatus were used as on the previous tests.

A test was started on May 24th, but owing to the stack temperatures being unreasonably high, it was decided to shut down the boilers for inspection. During the interval the boiler tubes were drilled inside, well cleaned outside, and the baffles were repaired. Considerable dirt was found on the outside of the tubes. This dirt had been carried into the boilers a few days prior to starting tests while the furnace men had been flushing the gas mains.

The testing was resumed on May 31st. Tests 37 to 40, inclusive, were run on No. 1 boiler with the object of obtaining points to plot an efficiency load curve with the most efficient air regulation for each point. During these tests the damper was wide open and before each test the primary and secondary air openings of burner C were adjusted to give the best analysis for the desired gas pressure. The pressure in the boiler gas header was held constant over each test period by manipulating the butterfly valve in the down-comer. Test 37 was made with a gas pressure of 1.2 ins. water in the header. This was the maximum amount of gas the boiler would take. When given more, the gas back-fired in the burner.

Test 42 was a check on test 37. Both were made under the same conditions, except that in test 42 the secondary air ports were open 3 inches instead of 2 inches

as in test 37. The object of this check was to try to cut down the CO that appeared in test 37, also to note what changes in efficiency would follow. The principal results of tests 37 to 42 are plotted in curve sheet 4, showing that burner C gave 66 to 70 per cent. efficiency for rates of evaporation varying from .92 to 1.40 per cent. rating. These results represent almost ideal conditions, the tubes being clean, setting tight and burners regulated with aid of gas analyses.

It was then decided to make some comparative tests of burners B and C. Test 44 was made first with each boiler making about ten per cent. overrating, which was the maximum load which could be maintained. Tests 45 and 46 were then made on both boilers, but at a lower capacity.

These tests showed that with equal expert attention, aided by gas analyses, burners B and C gave practically the same results, varying from 64 to 69 per cent. efficiency at loads between 66 and 114 per cent. rating.

Furnace temperatures were taken during the tests 39 to 46 with a Scimatco optical pyrometer. The temperatures were read at the same location in both boilers, namely, at the checkers which are at the rear of the grates. From these initial temperatures and other data the theoretical stack temperatures were calculated and found to agree very closely with the actual stack temperatures. This not only served as a check on the data obtained, but it also showed that very little burning of the gases took place beyond the point where the furnace temperatures were read.

Tests 47, 48 and 49 were made on May 12th. Both types of burners were adjusted by the boiler house foreman to the best of his ability. He had no knowledge of the condition of combustion nor the header pressure before adjusting the burners. After he had set the burners to his own satisfaction, the observers noted the header pressure and maintained it constant until a test was run. The manner of conducting these tests was the same as

in the previous ones. The boilers were run at three different rates of evaporation. In making these tests, the object was to see what results could be obtained by the firemen in actual operation without the aid of any scientific observations. The results may be seen in Table V. Type B burner gave about two per cent. higher efficiencies than type C. It will be noted that in tests 47 to 49 the efficiencies are somewhat lower than in the previous tests 37 to 42. This is due to the fact that the boiler tubes had not been blown for nearly two weeks, resulting in 200 degrees higher stack temperatures for the same loads. The combustion, however, was equally as good in the latter tests as in the previous ones.

In these tests, as in all others, it should be borne in mind that the settings and boiler conditions in general were better than in normal practice, therefore none of the tests can be interpreted as a comparison between first-class equipment operated with care and ordinary equipment with perfunctory attention. Many prior tests indicate that the usual efficiency over long periods does not exceed 55 per cent., while these tests make it manifest that 60 or 65 per cent. is easily obtainable with closer attention to keeping up physical condition of the boiler plant, even without additional expenditure for special types of burners. As high as 70 per cent. may be obtained from ordinary types of boilers equipped with the better class of burners when given expert attention under favorable operating conditions.

Tests with Burner E on Wheeler Boilers—Table VI

TESTS OF BURNERS FOR BLAST FURNACE GAS IN WHEELER BOILER

WASHED GAS AT NORMAL PRESSURE

Aug. 16 and 19, 1915

Test Number		50	51	52	53
Boiler Number		6	6	6	6
Burner		E	E	E	E
Date		8/16/15	8/16/15	8/19/15	8/19/15
Duration of Test	Hours	1.00	1.00	1.00	1.00
Average Pressures:					
Steam at Boiler by Gauge	Lb. Per Sq. In.	140	140	133	130
Draft Under Damper	Ins. Water	—.36	—.34	....	....
Draft in Furnace	"	....	....	....	....
Gas Pressure in Main	"	3.5	3.5	7.0	5.0

Gas Pressure in Boiler Gas Header	Ins. Water	....	....	....	....
Lbs. Pressure Through Burner	"	....	....	....	....
Average Temperatures:					
Fuel Gas in Main.......	Deg. F.	175	175	175	175
Feed Water Entering Boiler	"	240	240	250	250
Stack Gases	"	704	640	796	777
Superheat of Steam......	"	20	20	20	20
Fuel:					
Gas Per Hr. (Calculated) Std. Cond.	Cu. Ft.	176300	141400	219000	183500
Gas Per Boiler Horse Power	"	479	512.5	502	500
Analysis of Fuel Gas:					
Carbon Dioxide CO_2....	%	15.2	15.2	15.2	15.2
Oxygen O	%	0.0	0.0	0.0	0.0
Carbon Monoxide CO	%	21.6	21.6	21.6	21.6
Hydrogen H	%	5.78	5.78	5.78	5.78
Methane CH_4....	%	1.45	1.45	1.45	1.45
Calorific Value of Dry Fuel Gas:					
Per Cu. Ft., High Value, Std. Conds.	B.T.U.	104.0	104.0	104.0	104.0
Per Lb., High Value.....	"	1379.0	1379.0	1379.0	1370.0
Per Cu. Ft., Incl. Sens. and Latent Heat	"	111.5	111.5	111.5	111.5
Per Lb., Incl. Sens. and Latent Heat	"	1472.1	1472.1	1472.1	1472.1
Analysis of Flue Gas:					
Carbon dioxide CO_2....	%	21.0	15.5	21.6	21.4
Oxygen O	%	4.8	9.1	3.4	5.2
Carbon Monoxide CO	%	0.0	0.0	0.0	0.0
Nitrogen N (By Difference)	%	74.2	75.4	75.0	73.4
Water Per Hour:					
Evap. as Read by Steam Flow Meter		12330	9260	14780	12570
Factor of Evaporation....		1.028	1.028	1.0175	1.017
Equiv. Evap. from and at 212° F................	Lb. Per Hr.	12690	9520	15040	12790
Horse Power:					
On Basis of 34.5 Lb from and at 212° F.........	B.H.P.	368	276	436	367
Builders' Rating on 10 Sq. Ft. Heating Surface...	"	355	355	355	355
Per Cent. Rating Developed	%	103.7	77.7	122.8	103.4
Efficiency:					
Stack Losses (Calculated from Flue Gas Conditions)	%	32.3	36.4	35.2	34.9
Radiation and Unaccounted Losses (Assumed)..	%	5.0	5.0	5.0	5.0
Boiler Efficiency (By Difference)	%	62.7	58.6	59.8	60.1

All of the foregoing tests were made on Stirling and Rust boilers from which it had been repeatedly demonstrated in many prior tests that good efficiencies were obtainable by giving proper attention to upkeep and systematic regulation of burners and dampers. Manifestly the degree of improvement following the installation of improved burners of the Birkholz type could not be so great with such boilers as with boilers of the single pass arrangement such as the Cahall and Wheeler. The latter types, as usually set, have a relatively small combustion chamber and therefore inadequate space for proper mixing of air and gas when the latter is pro-

jected at high velocity through the narrow orifice burner designated herein as type A. High stack temperatures, resulting from partial combustion beyond the limits of the furnace, are characteristic of these boilers and all attempts to remedy the evils have been unsuccessful. Inasmuch as the characteristic mixing action of the Birkholz burner had been found favorable when applied to Rust and Stirling boilers, the sixth series of tests was conducted on a Wheeler boiler rated at 355 horse-power. The boiler was equipped with four Birkholz burners of type E, two burners being on each side of the boiler, all pointing downward at an angle of about 22 degrees. The gas received by the boiler was a mixture of raw and washed gas, thus accounting for the 170 degree raw gas temperature. As heretofore, the evaporation of the boiler was measured by means of a General Electric recording flow meter. The stack temperature was taken every five minutes by means of a thermo-couple installed in the breeching of the boiler. Continuous stack gas samples were taken at the same point at which the stack gas temperatures were taken. The temperature of the raw gas was taken every 15 minutes by a thermometer inserted in the large main supplying gas to the boilers. Gas pressure in the main was taken by means of a Bristol recording pressure gauge. Continuous samples were taken of the raw gas, gas pressure in the main, steam pressure and feed water temperatures were obtained from recording gauges. During the four tests the boiler was on hand feed, so that a good record could be obtained on the flow meter.

Before starting the tests proper, stack gas analyses were taken with the following results:

CO_2	17.9%
O_2	6.5%
CO	0.0%

indicating considerable air leakage in the boiler setting. The settings were then plastered up and afterwards painted with a mixture of tar and asbestos cement so

that nearly all the air leakage through the setting and around the breeching was eliminated. Four one hour tests were then run on the burner. During the tests three burners were used, as it was found that boiler rating could easily be maintained with three.

Tests 50 and 51 were run on August 16th. In test 50 the gas gate valves were open the same distance. The air slides of the burners were wide open and the small end of the air nozzle was located exactly at the throat of the gas nozzle. No attempt was made to regulate the gas pressure. In test 51 the same conditions prevailed except that the burner valves were open only 5 ins. on the stem. Test 51 as compared with 50 again demonstrates the fact that the burner was not entirely automatic for different gas pressures.

For tests 52 and 53 the gas pressure was maintained constant throughout each test by manipulating the gate valves.

At this time no tests were made for comparing burner E with burner A, which is the type used on the other boilers in this house, but it was plainly evident from observing the condition of the combustion chamber that better combustion and higher furnace temperatures were being maintained with Birkholz burners. The improvement in furnace combustion was very obvious when viewed through the burner openings and cleaning doors in the boiler setting. Whereas the usual condition was a smoky furnace of low red color with flame extending high into the heating surface, the Birkholz burner gave a transparent white flame of 2000 to 2100 degrees temperature, by pyrometer measurement, with practically complete combustion within the limits of the furnace. Prior tests on the old type of burner A in this boiler house gave from 16 to 18 per cent. CO_2, while burner E showed 21 and 22 per cent. with very little attention to regulation.

A special test was conducted on the Birkholz-Terbeck burner to determine, if possible, whether sufficient air for combustion was induced by the velocity of the gas

through the burner nozzles. The damper was wide open producing a stack draft of .77 in. and a furnace draft of .45 in. The burners were adjusted so that the first set of primary air ports were wide open, the second set of primary air ports one-half open and the secondary ports one-quarter open. This arrangement gave good combustion. Continuous samples were taken of the stack gases every 10 minutes for a period of one hour and showed the following average results:

CO_2	23.6
O_2	2.4
CO	.1
Stack Temperature	937° F.
Evaporation	328 B.H.P.

Having established the conditions as above noted, the damper was partly closed until the stack draft was reduced from .77 in. to .35 in. and as a consequence the furnace draft dropped from .45 in. to .13 in. The gas pressure in the header remained the same as before and the air ports settings on the burner were not altered. The resulting temperatures and analyses were as follows:

CO_2	24.6
O_2	1.0
CO	2.0
Stack Temperature	863° F.
Evaporation	328 B.H.P.

A comparison of this analysis with that of the previous test indicated that the induction effect alone was not sufficient to give all the air required for complete combustion.

The next operation was to increase the gas pressure to 3 inches in the gas header. Other adjustments remained the same as given above except that all primary ports were opened wide. The evaporation with these changed conditions dropped to about 210 B. H. P. With gas pressure maintained at 3 inches and the damper in the same position, the secondary air ports were opened wide, that is, all air ports were wide open. The resulting temperatures and analyses were:

CO_2	21.6
O_2	2.1
CO	3.3
Stack Temperature...	820° F.
Evaporation	255 B.H.P.

These results indicate that even with an excess of air, the mixing effect in the burner and furnace was not adequate to give complete combustion.

Keeping the gas pressure at 3 inches and all air ports wide open, the damper was then opened so that the stack draft became .73 in. and the furnace draft .16 in. The resulting observations showed:

CO_2	22.5
O_2	3.1
CO	0.0
Stack Temperature...	931° F.
Evaporation	375 B.H.P.

As a result of the foregoing special tests, it is evident that the air necessary for combustion is to a great extent influenced by the stack draft and not entirely by the aspirating effect of the gas velocity in the burner nozzles.

At the Ohio Works of the Carnegie Steel Company, tests were conducted on two 400 H. P. Stirling boilers fired with mixed rough and washed blast furnace gas.

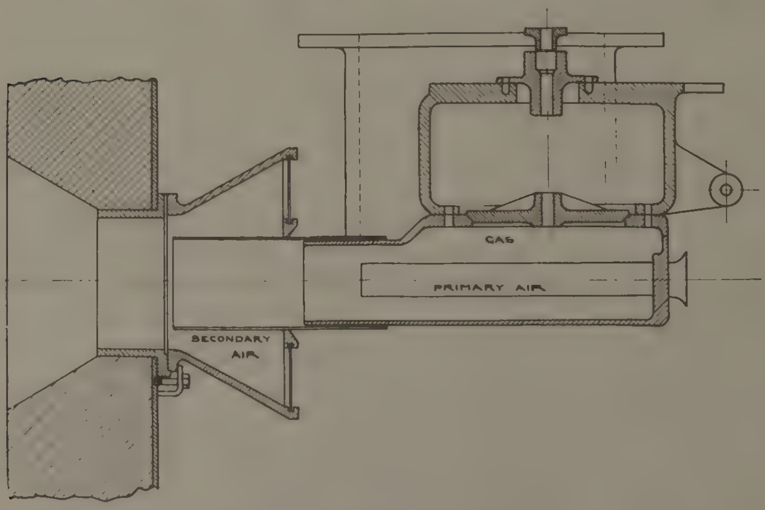
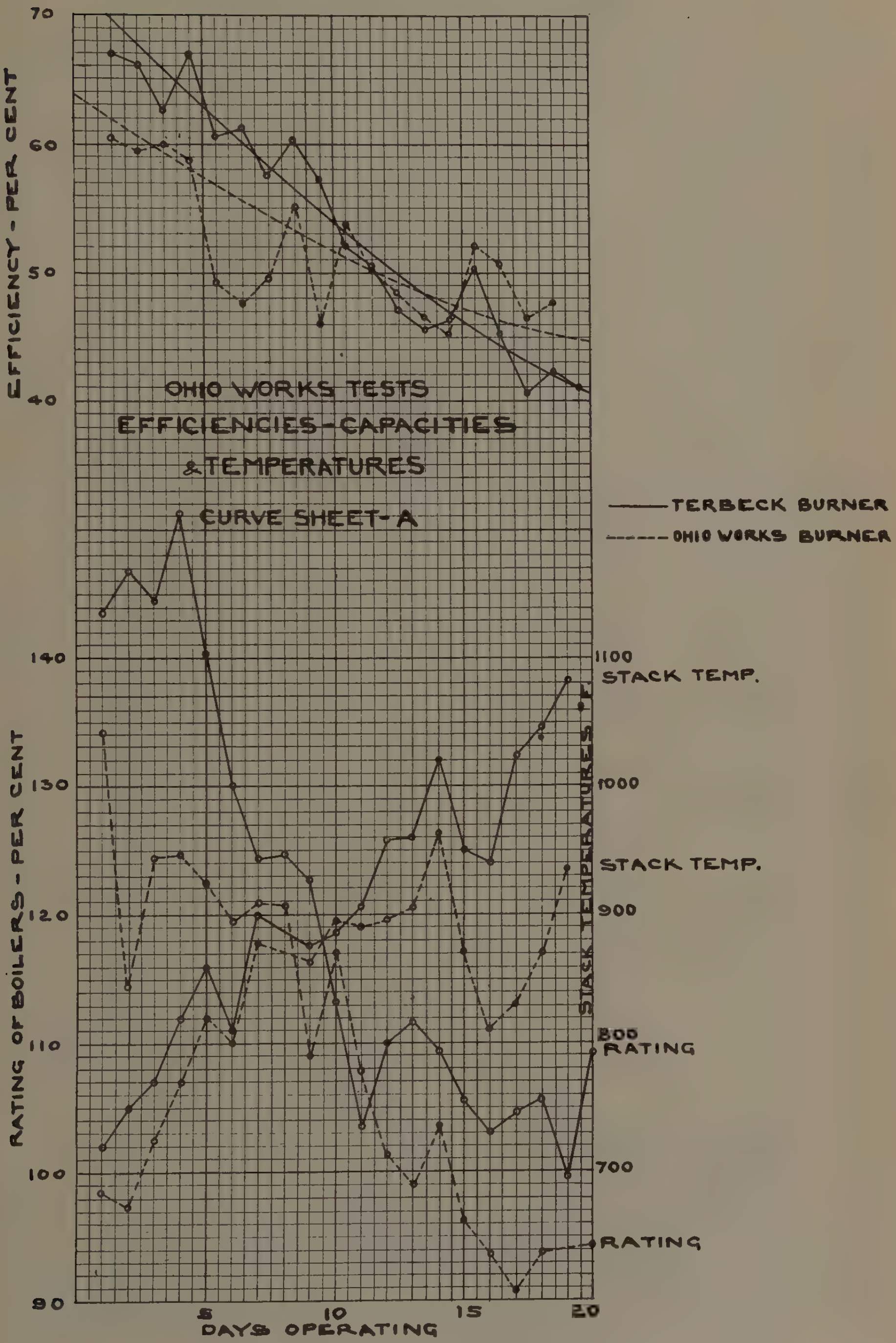


Fig. 12. Ohio Works Burner


OHIO WORKS TESTS
EFFICIENCIES–CAPACITIES & TEMPERATURES
CURVE SHEET–A
TERBECK BURNER
OHIO WORKS BURNER
EFFICIENCY - PER CENT
70
60
50
40
RATING OF BOILERS - PER CENT
140
130
120
110
100
90
STACK TEMPERATURES °F.
1100
1000
900
800
700
STACK TEMP.
STACK TEMP.
RATING
RATING
5
10
15
20
DAYS OPERATING

One boiler was equipped with a Birkholz Terbeck burner, similar to Fig. 11 (page 354), and the other with the Ohio Works burner, Fig. 12. Continuous tests were run for nineteen days, results being shown on curve sheet A.

The rapid decrease in efficiencies and capacities of both boilers and the high stack temperatures is due to accumulation of flue dust which cannot be blown from the tubes, the boilers being too close together to permit free use of good blowing apparatus. Owing to this condition the boilers are taken out of service at frequent intervals and the dust removed.

The following figures are taken from a twenty-four hour complete test, run when the boilers were comparatively clean, and indicate that the burners are of about equal merit, the four per cent. higher efficiency of the Berkholz Terbeck being attributed to the fact that the setting of the boiler on which it was tested was in better condition than the other boiler. The data from this test has been used to calculate efficiencies by the indirect method, for sake of comparison with the other tests quoted.

			Birkholz-Terbeck.	*Ohio Works Fig. 12.*
Per cent. of Rating Developed......		%	136.5	123.3
Blast Furnace Gas Analysis..	CO_2	%	14.4	14.4
	CO	%	24.8	24.8
	CH_4	%	0.6	0.6
	H_2	%	2.5	2.5
Combustion Chamber Gas Analysis	CO_2	%	....	....
	O_2	%	....	....
	CO	%	....	....
Stack Gas Analysis..........	CO_2	%	23.2	19.9
	O_2	%	1.6	4.2
	CO	%	0.6	0.8
Gas Pressure......................		Ins. H_2O	3.7	3.7
Furnace Draft....................		" "	....	....
Furnace Gas Temperature.........		Deg. F.	210	210
Combustion Chamber Temperature.		" "	....	....
Stack Temperature................		" "	790	760
Calorific Value of Fce. Gas per Cu. Ft.........................		B.T.U.	92.8	92.8
Sensible Heat in Fce. Gas per Cu. Ft.		"	3.0	3.0
Total Heat in Fce. Gas per Cu. Ft.		"	95.8	95.8

		Birkholz-Terbeck.	*Ohio Works Fig. 12.*
Sensible Heat Loss in Stack........	%	28.6	30.8
Unconsumed CO Loss in Stack.....	%	3.3	5.1
Radiation	%	5.0	5.0
Efficiency	%	63.1	59.1

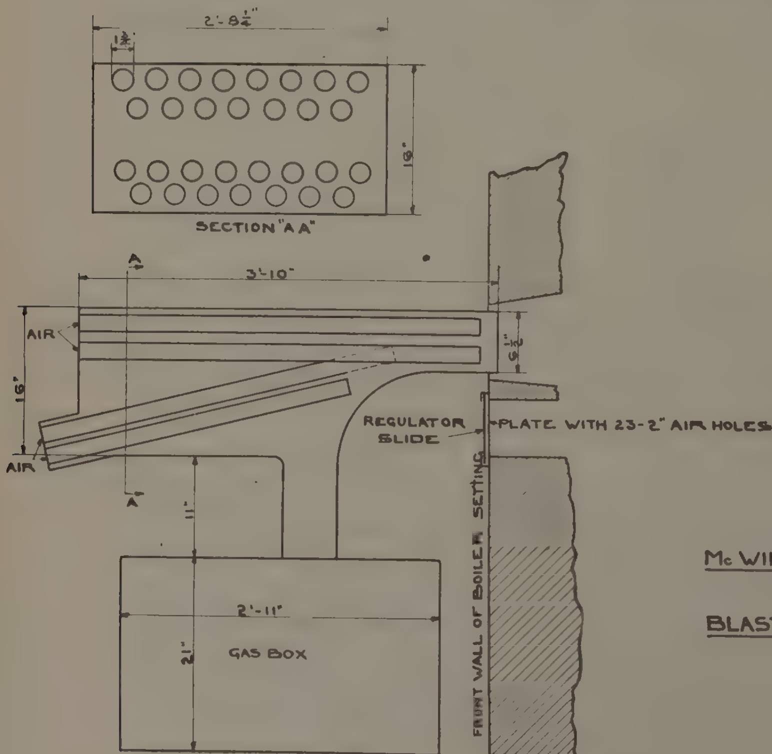
Comparative tests at Wisconsin Steel Co., were made on two 350 H. P. Stirling boilers side by side, one with the Birkholz-Terbeck and the other with the common burner. The efficiencies were calculated on a basis of Pitot tube measurements of the gas and show decided differences in efficiencies between the boilers equipped with the two types of burners, although the outputs and stack analyses were the same and the stack temperatures only 37° F. different, corresponding to only about 2 per cent. difference in efficiencies. The data from these tests calculated by the indirect method, for sake of comparison with other tests reported in this paper, gives the following results:

BIRKHOLZ-TERBECK AND COMMON BURNER, WISCONSIN STEEL CO.

First Test.			*Birkholz-Terbeck Burner.*	*Common Burner.*
Per cent. of Rating Developed......			127	130
Blast Fcé. Gas Analysis......	CO_2	%	15.1	15.1
	CO		23.6	23.6
	H_2		3.0	3.0
Comb. Chamber Gas Analysis.	CO_2	%	....	....
	O_2		....	....
	CO		....	....
Stack Gas Analysis...........	CO_2	%	21.1	20.8
	O_2		3.6	4.3
	CO		0.0	0.0
Gas Pressure.....................		Ins. H_2O	....	....
Furnace Draft....................		" "	....	....
Furnace Gas Temperature.........		°F.	267	267
Combustion Chamber Temperature.		°F.	....	....
Stack Temperature................		°F.	615	652
Calorific Value of Fce. Gas per Cu. Ft..........................		B.T.U.	84.8	84.8
Sensible Heat in Fce. Gas per Cu. Ft.		"	4.1	4.1
Total Heat in Fce. Gas per Cu. Ft.		"	88.9	88.9

First Test.		Birkholz-Terbeck Burner.	Common Burner.
Sensible Heat Loss in Stack.......	%	25.8	28.0
Unconsumed CO Loss in Stack.....	"	0.0	0.0
Radiation Loss..................	"	5.0	5.0
Efficiency	"	69.2	67.0
Second Test.			
Poor Regulation on Common Burner.	Eff.....	68.4	59.2
Third Test.			
Poor Regulation on Common Burner.	Eff.....	71.4	59.7

While the Birkholz-Terbeck burner might require as much regulation as the common burner as indicated by tests, yet much credit must be given it as a neatly designed and easy method of adjusting air admissions. The means of observing the combustion through the glass window rather than through a peep hole is also a decided advantage. These elements are all conducive to



McWILLIAMS BURNER FOR BLAST FURNACE GAS

Fig. 13

closer attention and increase the morale of an installation resulting in far better unaccounted for efficiency than the placing of a brick or a ball of clay to exclude or admit varying quantities of air. Under test conditions these points would not be so apparent as under the ordinary operating periods where the observation is not so marked.

Figure 13 illustrates the McWilliams burner, of much the same principle as the Youngstown burner, but having four banks of tubes. There is practically no space for mixing in the burner and the combustion is no better than the common burner.

The table of air drafts given below shows that the draft, due to aspirating effect, increases with gas quantity, but not in direct proportion. Correct mixtures were not obtained, and the seemingly large amount of air supplied through the burner is actually but a small part of the total required for complete combustion.

For the two series of draft readings, given in the following table, the damper was kept in constant position.

Location	400 B.H.P. Ins. H_2O	540 B.H.P.
Top row of pipes	.35	.50
2nd " " "	.39	.60
3rd " " "	.23	.32
4th " " "	.18	.31
Holes in setting under boiler	.10	.05
Between burner and setting	.35	.48
Stack breeching (3 ft. from boiler)	1.00	1.01

It should be noted that in the holes in setting under burner the draft decreases with increased gas quantity, showing that the aspirating effect in such locations is negative, as would be expected, since with a constant position of stack damper, the pressure in the combustion chamber must increase with quantities handled. There is a small aspirating effect all around the gas jet, but its sphere of influence extends less than an inch in each direction. A series of six complete 8-hour tests on this burner follows:

OPERATION OF BOILER WITH McWILLIAMS BURNER.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 2.—250 H.P., B. & W. BOILERS.
TESTS TO DETERMINE STATE OF COMBUSTION.

Date		3/30/15	3/31/15	4/1/15	4/2/15	4/3/15	4/3/15
Boiler No.		10	10	10	10	10	10
Style of Burner and Fuel		McWilliams Burner (Fig. 13). Rough Gas.					
B.H.P. Developed		565	568	590	545	450	450
Per Cent. of Rating Developed		226	227	236	218	180	180
Furnace Gas Analysis (Dry)	CO_2	14.0	14.2	12.6	14.2	13.5	13.5
	CO	24.8	24.2	24.6	24.6	24.1	24.1
	H_2	3.5	3.4	3.6	3.6	3.4	3.4
Comb. Chamber Gas Analysis (Dry)	CO_2	....	23.8	21.6	21.3	22.6	24.2
	O_2	....	0.3	0.4	0.7	1.2	0.2
	CO	....	6.4	10.0	9.3	4.6	4.1
3rd Pass Analysis (Dry)	CO_2						
	O_2	Not Taken.					
	CO						
Stack Gas Analysis (Dry)	CO_2	12.7	14.1	13.6	14.5	16.2	11.6
	O_2	10.5	9.5	9.7	9.1	7.4	11.7
	CO	0.7	0.7	0.6	0.5	0.2	0.1
Ratio { Furnace Gas (Dry) / C. C. Gas (Wet) }		....	1.37	1.27	1.37	1.49	1.43
Air Excess, 3rd Pass, %		....	....	....	....	....	....
Ratio { Furnace Gas (Dry) / Stack Gas (Wet) }		3.06	2.75	2.78	2.74	2.43	3.41
Air Excess, Stack, %		221	180	182	167	123	272
Steam Pressure, Lbs.		140	145	130	143	151	151
Gas Pressure, Ins. H_2O		4.0	4.0	4.0	4.0	3.5	3.5
Feed Water Temperature, °F.		168	165	161	161	165	165
Furnace Gas Temperature, °F.		380	400	472	394	330	350
Combustion Chamber Temperature, °F.		....	1925	1975	1930	1820	1870
Stack Temperature, °F.		640	625	675	670	680	700
Calorific Value of Gas, B.T.U.		90.1	87.8	89.7	89.7	87.5	87.5
Sensible Heat in Gas, B.T.U.		6.4	6.9	8.3	6.8	5.4	5.8
Total Heat in Gas, B.T.U.		96.5	94.7	98.0	96.5	92.9	93.3
Stack Loss per Cu. Ft., B.T.U.		12.0	11.7	12.7	12.5	13.0	13.2
Stack Loss per Cu. Ft. Fce. Gas, B.T.U.		36.8	32.2	35.3	34.2	31.6	45.0
CO Loss per Cu. Ft. Fce. Gas, B.T.U.		6.9	6.2	5.4	4.4	1.6	1.1
Stack Loss, %		38.1	34.0	36.0	35.4	34.0	48.2
CO Loss, %		7.2	6.6	5.5	4.6	1.7	1.2
Radiation Loss, %		5.0	5.0	5.0	5.0	5.0	5.0
Efficiency, %		49.7	54.4	53.5	55.0	59.3	45.6

Remarks

Test on 3/30/15.

The 49.7% efficiency is about the average operation of the boiler as found.

Tests on 3/31, 4/1 and 4/2/15.

54.4%, 53.5% and 55.0% respectively, are for the best conditions obtained by having doors fastened tightly, mudding up all large openings in setting and admitting more air by moving back the screen around the burners.

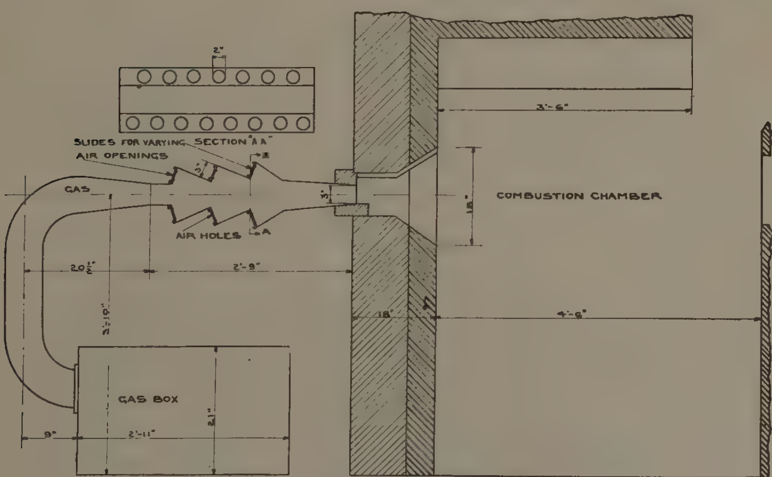
Test on 4/3/15.

59.3% was obtained at 450 B.H.P. capacity by closing the stack damper as much as possible for a long enough time to obtain a sample. The condition was not practical for regular operation because of excessive blowing out of gas around doors, etc.

Test on 4/3/15.

45.6% was obtained having the stack damper opened as it is in ordinary operation.

Type 3—Rectangular or circular burner with all air required for combustion conducted into the gas jet by means of pipes or other openings.



DUQUESNE
ASPIRATING BLAST FURNACE GAS BURNER
FIG. 14

This principle was followed in the design of an aspirating burner made at Duquesne for experimental purposes, and shown in Fig. 14. It consists of a series of air vanes at top and bottom of burner, the gas jet being contracted at each vane but each contracted area made larger than the preceding one. Operated at about the rated capacity of the boiler, 250 H.P. B & W, a burner efficiency of 92% was obtained, but on increasing the capacity the efficiency dropped rapidly, due to unconsumed CO. The inability of the burner to aspirate when burning large amounts of gas was probably due to the converging outlet. Had this outlet been made wider and diverging, it is possible that much better results would have been obtained. Tests results of this burner follow:

Per cent. of Rating Developed		108
Furnace Gas Analysis	CO	25.4
	H_2	3.8
	CO_2 %	23.4
Combustion Chamber Analysis	O_2	.9
	CO	.9
	CO_2 %	17.2
Stack Gas Analysis	O_2	5.7
	CO	0.3
	CO_2 %	12.6
Gas Pressure		3.5
Draft in Furnace		.25
Furnace Gas Temperature, °F		375
Combustion Chamber Temperature, °F		1870
Stack Temperature, °F		560
Calorific Value of Fce. Gas Cu. Ft. B.T.U		92.9
Sensible Heat of Fce. Gas Cu. Ft. B.T.U		6.3
Total Heat of Fce. Gas Cu. Ft. B.T.U		99.2
Sensible Heat Lost in Stack, %		29.2
Unconsumed CO Lost in Stack, %		2.1
Radiation		5.0
Efficiency		63.7

Following is a series of seven 8-hour tests of this burner run in conjunction with tests of a common burner on an adjoining boiler. While nearly the correct amount of air was admitted through the burner as shown by the combustion chamber analyses, the poor condition of setting prevented good stack analyses.

OPERATION OF BOILERS WITH ASPIRATING BURNER AND COMMON BURNER.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 4.—250 H.P., B. & W. BOILERS.
TESTS TO DETERMINE STATE OF COMBUSTION.

Date		7/28/14		7/31/14		8/6/14		8/7/14	
Boiler No.		11	12	11	12	11	12	11	12
Style of Burner and Fuel		Aspirating Burner (Fig. 14) on No. 11. Rough Gas. Common Burner on No. 12.							
B.H.P. Developed		310	350	270	402	266	287	245	353
Per cent. of Rating Developed		124	140	108	161	106	115	98	141
Furnace Gas Analysis (Dry)	CO_2	12.8		12.6		12.6		13.0	
	CO	25.1		25.4		24.6		25.8	
	H_2	4.0		3.8		4.6		4.0	
Comb. Chamber Gas Analysis (Dry)	CO_2	23.5	22.7	23.4	22.5	23.5	22.5	24.6	23.0
	O_2	1.1	1.2	0.9	1.8	0.8	1.5	0.7	1.3
	CO	1.7	2.0	0.9	2.5	3.0	3.1	2.7	3.0
3rd Pass Analysis (Dry)	CO_2	Not Taken.							
	O_2								
	CO								
Stack Gas Analysis (Dry)	CO_2	16.9	18.5	17.2	18.8	16.3	19.9	16.4	19.4
	O_2	6.2	5.6	5.7	5.1	6.7	4.3	6.7	5.4
	CO	0.4	0.2	0.3	0.4	0.3	0.4	0.5	0.3
Ratio Furnace Gas (Dry) / C. C. Gas (Wet)		2.36	2.19	2.34	2.14	2.42	1.98	2.48	2.13
Air Excess, 3rd Pass, %		....	....	....	....	....	....	....	....
Ratio Furnace Gas (Dry) / Stack Gas (Wet)		2.32	2.14	2.30	2.10	2.37	1.96	2.43	2.10
Air Excess, Stack, %		96	79	86	71	105	55	106	72
Steam Pressure, Lbs.		142		140		139		149	
Gas Pressure, Ins. H_2O		2.8		2.4		2.6		2.6	
Feed Water Temperature, °F.		198		200		201		202	
Furnace Gas Temperature, °F.		366		375		358		312	
Combustion Chamber Temperature, °F.		1890	1840	1870	1810	1810	1830	1830	1840
Stack Temperature, °F.		750	850	660	810	590	800	655	870
Calorific Value of Gas, B.T.U.		92.5		92.9		92.5		94.7	
Sensible Heat in Gas, B.T.U.		6.1		6.3		6.0		5.0	
Total Heat in Gas, B.T.U.		98.6		99.2		98.5		99.7	
Stack Loss per Cu. Ft., B.T.U.		14.6	17.2	12.6	16.3	11.2	16.1	12.5	17.6
Stack Loss per Cu. Ft. Fce. Gas, B.T.U.		33.9	36.8	29.0	34.2	26.5	31.5	30.4	37.0
CO Loss per Cu. Ft. Fce. Gas, B.T.U.		2.8	1.3	2.1	2.6	2.2	2.4	3.7	1.9
Stack Loss, %		34.4	37.3	29.2	34.5	26.9	32.0	30.5	37.1
CO Loss, %		2.8	1.3	2.1	2.6	2.2	2.4	3.7	1.9
Radiation Loss, %		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Efficiency, %		57.8	56.4	63.7	57.9	65.9	60.6	60.8	56.0

OPERATION OF BOILERS WITH ASPIRATING BURNER AND COMMON BURNER.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 4.—250 H. P., B. & W. BOILERS.
TESTS TO DETERMINE STATE OF COMBUSTION.

Date		8/11/14		8/12/14		8/13/14	
Boiler No.		11	12	11	12	11	12
Style of Burner and Fuel		Aspirating Burner (Fig. 14) on No. 11. Rough Gas. Common Burner on No. 12.					
B.H.P. Developed		290	419	278	397	261	410
Per cent. of Rating Developed		116	168	111	159	104	164
Furnace Gas Analysis (Dry)	CO_2	12.1		12.4		12.4	
	CO	26.0		25.8		25.4	
	H_2	4.7		4.4		4.2	
Comb. Chamber Gas Analysis (Dry)	CO_2	22.4	21.9	22.4	23.3	22.9	22.9
	O_2	1.6	1.6	1.7	1.0	1.7	0.7
	CO	1.6	2.9	1.6	3.2	1.5	4.1
3rd Pass Analysis (Dry)	CO_2, O_2, CO	Not Taken.					
Stack Gas Analysis (Dry)	CO_2	16.6	18.9	16.9	20.4	16.4	20.2
	O_2	6.7	4.5	6.4	3.9	6.8	3.9
	CO	0.4	0.4	0.4	0.4	0.3	0.4
Ratio { Furnace Gas (Dry) / C. C. Gas (Wet) }		2.42	2.13	2.38	1.98	2.44	1.98
Air Excess, 3rd Pass, %		....	....	....	....	....	....
Ratio { Furnace Gas (Dry) / Stack Gas (Wet) }		2.38	2.11	2.34	1.96	2.40	1.96
Air Excess, Stack, %		100	59	95	48	106	49
Steam Pressure, Lbs.		148		144		145	
Gas Pressure, Ins. H_2O		3.0		....		....	
Feed Water Temperature, °F.		194		192		198	
Furnace Gas Temperature, °F.		345		328		334	
Combustion Chamber Temperature, °F.		1830	1780	1830	1840	1800	1860
Stack Temperature, °F.		695	870	720	910	660	885
Calorific Value of Gas, B.T.U.		97.3		95.8		94.0	
Sensible Heat in Gas, B.T.U.		5.7		5.4		5.5	
Total Heat in Gas, B.T.U.		103.0		101.2		99.5	
Stack Loss per Cu. Ft., B.T.U.		13.4	17.6	13.9	18.5	12.6	17.9
Stack Loss per Cu. Ft. Fce. Gas, B.T.U.		31.9	37.1	32.5	36.2	30.2	35.1
CO Loss per Cu. Ft. Fce. Gas, B.T.U.		2.9	2.6	2.9	2.4	2.2	2.4
Stack Loss, %		31.0	36.0	32.1	35.7	30.3	35.3
CO Loss, %		2.8	2.5	2.9	2.4	2.2	2.4
Radiation Loss, %		5.0	5.0	5.0	5.0	5.0	5.0
Efficiency, %		61.2	56.5	60.0	56.9	62.5	57.3

Following this type is also the Bradshaw burner shown in Fig. 15, which is supposed to follow the Venturi meter principle. It consists of a rectangular casting, through which gas passes. Air is admitted through narrow openings, top and bottom, the width of the burner. At this point the casting is contracted and the reduction in pressure due to increase in velocity provides the medium for air aspiration.

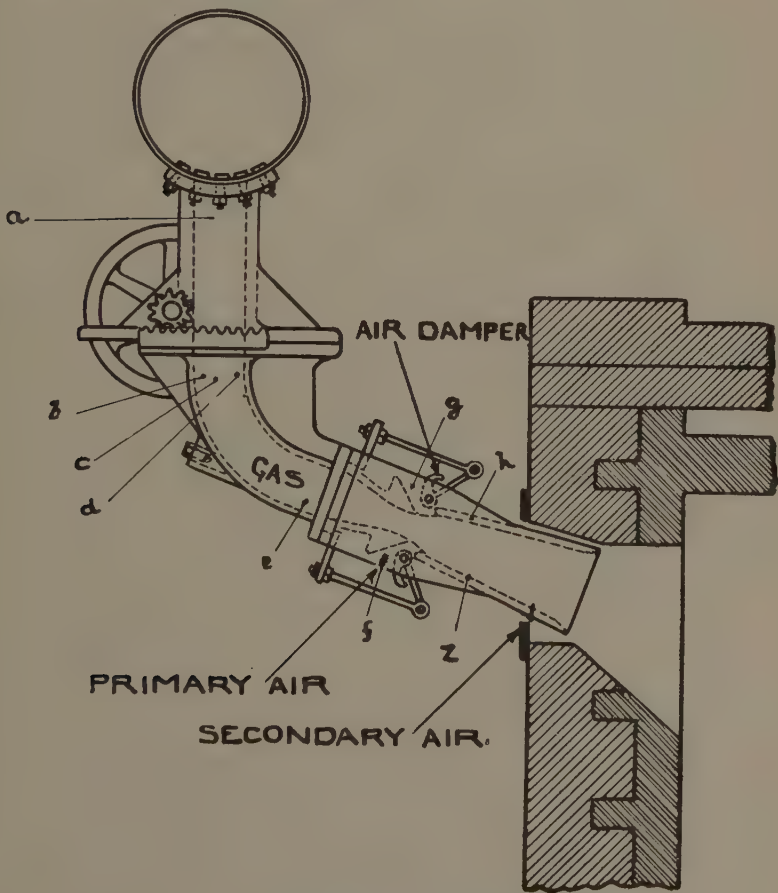


Fig. 15. Bradshaw Burner for Blast Furnace Gas

The casting then flares out to permit expansion from the throat of the burner into the furnace. It is claimed for this burner that there will be aspirated a quantity

of air in direct proportion to gas quantity for varying capacities. Experimental proof of this statement has been repeatedly requested from the designers but up to the present time has not been produced. In order to obtain this information, engineers from the Duquesne Works made experiments on Bradshaw burners installed on 500 H.P. Stirling boilers (Fig. 16) at the works of the Pittsburgh Steel Company, Monessen, Pa. At the same time comparative tests were made on modifications of the Bradshaw burner, designed by Mr. J. S. Fraser, Supt. of Blast Furnaces.

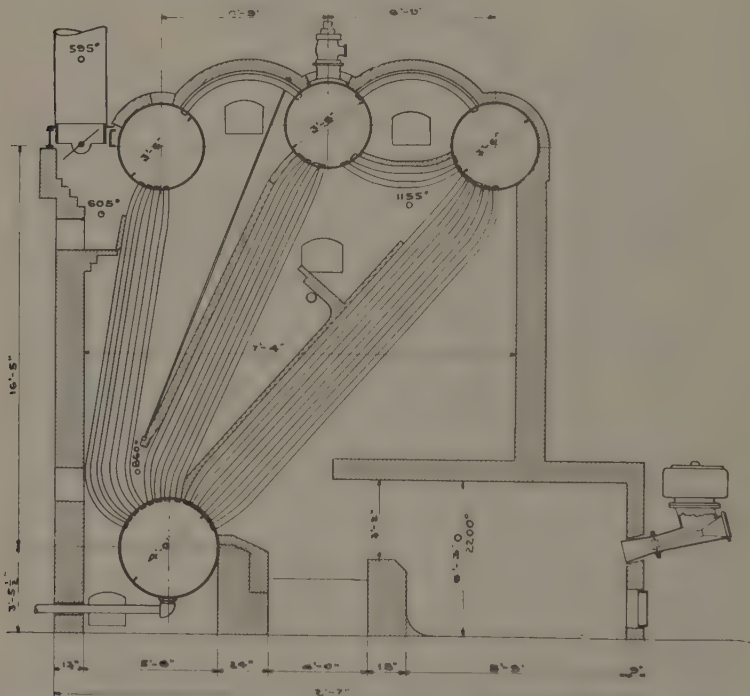
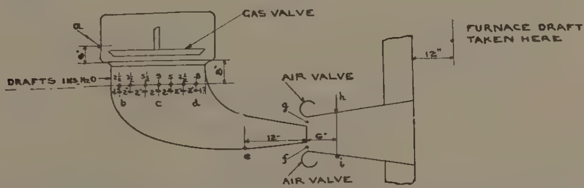


Fig. 16. 500 H.P. Stirling Boiler, Pittsburgh Steel Company, Monessen, Pa.

The makers of the Bradshaw burner state: first, that their best operation is by means of maintaining a constant furnace draft at a point which has been previously determined by test as giving correct air supply; second, that if this draft is maintained, the proper quan-

tities of air will be drawn into the burner over reasonable limits of gas pressure variation, say from 2″ to 10″ H_2O; third, that, without balanced draft, the average efficiency will be about 5% less than with it.

The experiments were made for this latter condition, in order to investigate the characteristics of the burner without automatic regulation. The damper was placed in a position to give a good gas analysis in combustion chamber at one gas pressure. Observations were then taken on air drafts and temperatures, with varying gas pressures, with results as shown in Table 7, the efficiency over the usual working range of pressure averaging 65.1%.



BURNER DATA										BOILER DATA													
		DRAFT AT POINTS								FURNACE			STACK GAS				HEAT BALANCE				REMARKS
													ANALYSIS								
RELATIVE OPENING ON GAS VALVE	GAS PRESSURE ABOVE VALVE POINT a	b	c	d	e	f	g	h	i	DRAFT	TEMP. °F.	STACK DAMPER OPENING	CO_2	O_2	CO	TEMP. °F.	SENSIBLE HEAT LOSS	CO LOSS	RADIATION	EFFICIENCY	
12	12	2.5	3	.8		.45	.15		.7	.15	2200	$\frac{2}{3}$ OPEN	17.8	6.0	.4	575	24.7	2.8	5.0	67.5	WORKING CONDITIONS
$11\frac{3}{4}$	14	$2\frac{1}{4}$	2.5	1		.40	.55			.20	2255	" "	15.2	8.1	0	530	27.8	0.0	5.0	67.2	GAS REDUCED
12	$13\frac{1}{2}$	2	2	$1\frac{3}{4}$		.50	.80		.65	.08	2155	" "	17.5	6.0	1.2	580	24.8	8.2	5.0	62.7	GAS INCREASED
$11\frac{3}{4}$	13	$2\frac{1}{2}$	$6\frac{1}{2}$	$2\frac{1}{2}$		.35	.35		.4	.20	2220	FULL	14.2	8.8	0	585	32.0	0.0	5.0	63.0	GAS REDUCED
$12\frac{1}{2}$	$11\frac{1}{2}$	$\frac{1}{2}+\frac{3}{4}$	$-2\frac{1}{2}$	0 TO 6		.60	.20	.75	.60	ATM.	DROPPED	"	NOT TAKEN								ENTIRELY TOO MUCH GAS

Test of Bradshaw Burner at Monessen
Table 7

The boiler test results show that with an increase of gas above the amount for which the original adjustments were made, there results 8.2% loss due to CO in the stack gases, proving that air in proportion has not been induced. Making due allowance for the 5% difference between balanced and unbalanced draft, we consider this a fair test of the aspirating possibilities of the burner.

Corresponding observations were made on Mr. Fraser's first modification of the Bradshaw burner which will be referred to hereafter as Fraser Burner #1. The main difference lies in taking air to the contracted por-

tion of the gas jet inside instead of outside. In this first design the side gas passages past the air box were made too small, resulting in only a small amount of gas passing under the air box.

Test results and observations of drafts and pressures follow. Several tests were run on both boilers, the best results in each case being presented. During these tests the gas valves remained in the same position, and adjustments made to stack damper. Consequently gas pressures indicate pressure in burner and quantity of gas burned. (See page 395.)

It will be noticed in the above table that the draft in air ports was small and did not vary with gas pressure, due to the poor aspirating effect of the restricted gas flow.

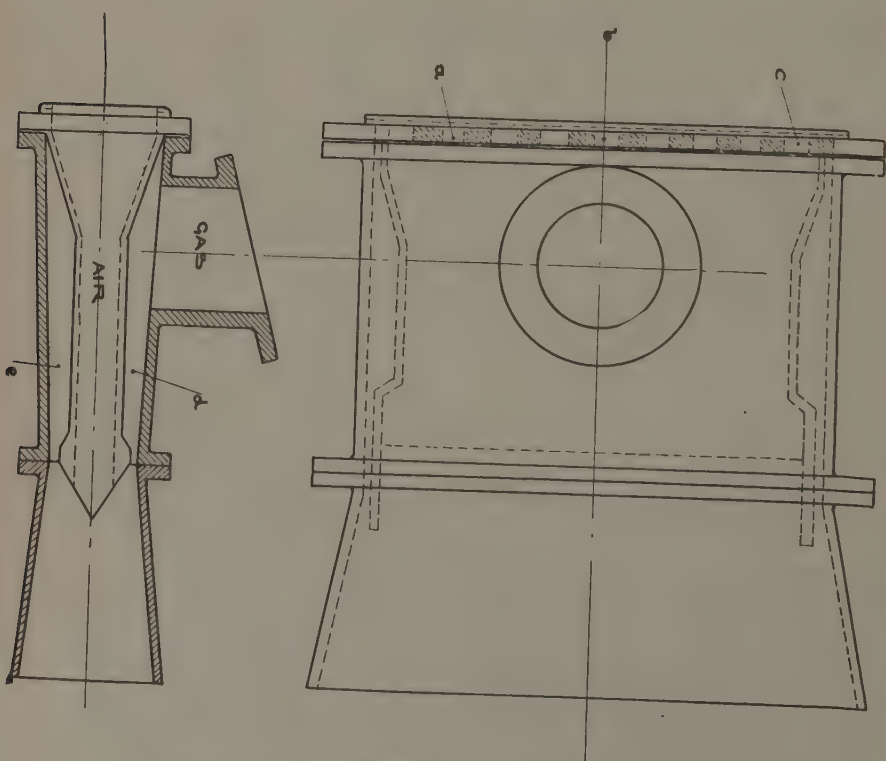


Fig. 17. Fraser's Modification of Bradshaw Gas Burner

TEST RESULTS FRASER BURNER NO. 1

Test Number		#1.	#2.	#3.	#4.	#5.	#6.	#7.
Per cent. Rating Developed		....	....	....	....	....	....	....
Furnace Gas Analysis	CO_2 %	13.2	13.2	13.2	13.2	13.2	13.2	13.2
	CO	27.1	27.1	27.1	27.1	27.1	27.1	27.1
	H_2	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Comb. Chamber Analysis	CO_2 %	21.2	22.8	23.3	23.6	23.9	23.6	24.0
	O_2	3.2	1.8	1.3	0.5	0.3	0.0	0.0
	CO	0.8	0.5	0.6	2.1	1.8	4.2	3.9
Stack Gas Analysis	CO_2 %	....	....	17.9	19.2	18.8	19.7	20.6
	O_2	....	....	5.7	3.9	4.0	3.3	2.9
	CO	....	....	0.2	1.1	1.2	4.1	3.0
Gas Pressure, Ins. H_2O		....	8½	13	14	14½	14	21½
Draft in Furnace, Ins. H_2O		.35	.19	.17	.12	.10	.05–.07	0–.05
Fce. Gas Temperature, °F		....	400	400	400	400	400	400
Comb. Chamber Temperature, °F		....	2180	2230	2250	2300	2085	2150
Stack Temperature, °F		....	....	570	615	595	540	605
Calorific Value Fce. Gas Cu. Ft., B.T.U		96.1	96.1	96.1	96.1	96.1	96.1	96.1
Sensible Heat Fce. Gas, B.T.U		6.7	6.7	6.7	6.7	6.7	6.7	6.7
Total Heat Fce. Gas Cu. Ft., B.T.U		102.8	102.8	102.8	102.8	102.8	102.8	102.8
Sensible Heat Lost in Stack, %		....	....	24.8	23.9	23.5	17.6	20.2
Unconsumed CO Lost in Stack, %		....	....	1.4	6.9	7.6	21.8	16.1
Radiation		....	....	5.0	5.0	5.0	5.0	5.0
Efficiency		....	....	68.8	64.2	63.9	55.6	58.7

Draft Readings Fraser Burner No. 1.

Draft in Air Ports.	Main.	Gas Pressures. Top Burner. (Point A).	Gas Pressures. Bottom Burner. (Point B).	Fce. Draft.	Remarks.
.33	9	4¾	13/16	.25	Working Conditions.
⅜	14	8½	1¼	....	" "
.38	8	4¼	¾	.28	" "
½	21	8¼	1⅝	.05	" "
⅜	21	8½	1¾	+ Atm.	(Damper partly closed. Temp. in C. C. dropped. Comb. very poor.)
.29	7			....	Combustion poor.
7/16	13			.15	" "
11/16	13½			.08	" "

Fraser Burner #2 (Fig. 17) was designed to provide ample passage for gas on sides of air box, which resulted in more nearly equal gas pressures at top and bottom of burners. Tests and draft observations follow:

Test of Fraser Burner No. 2.

		#1.	#2.	#3.	#4.
Per cent. of Rating Developed....		....	....	....	....
Furnace Gas Analysis....	CO_2 %	13.2	13.2	13.2	13.2
	CO	27.1	27.1	27.1	27.1
	H_2	3.0	3.0	3.0	3.0
Comb. Chamber Analysis.	CO_2 %	23.2	24.0	22.6	23.8
	O_2	2.5	0.5	3.1	1.9
	CO	0.6	2.9	0.2	0.7
Stack Gas Analysis.......	CO_2 %	18.8	18.6	18.7	16.9
	O_2	5.9	4.9	5.4	7.9
	CO	0.0	1.1	0.0	0.0
Gas Pressure, Ins. H_2O............		12½	14½	16½	9
Draft in Furnace, Ins. H_2O........		.08–.10	.19–.24	.05–.07	.31–.33
Fce. Gas Temperature, °F.........		360	340	330	330
Comb. Chamber Temperature, °F..		2190	2180	2190	2170
Stack Temperatures, °F...........		645	650	680	605
Cal. Val. Fce. Gas / Cu. Ft., B.T.U..		96.1	96.1	96.1	96.1
Sensible Heat F. Gas / Cu. Ft., B.T.U.		6.0	5.7	5.5	5.5
Total Heat Fce. Gas / Cu. Ft., B.T.U.		102.1	101.8	101.6	101.6
Sensible Heat Lost in Stack, %....		27.5	26.2	29.2	28.4
Unconsumed CO Lost in Stack, %.		0.0	7.1	0.0	0.0
Radiation, %....................		5.0	5.0	5.0	5.0
Efficiency, %....................		67.5	61.7	65.8	66.6
			(Unusual operation conditions.)		(Screens partly closed.)

The tests of Fraser Burner #2 show an average efficiency of 65.4% slightly better than shown by the Bradshaw Burner under the same operating conditions. Observations of the boilers also indicated very clearly that the Fraser Burner handled greater quantities of gas than the Bradshaw with the same gas pressure. The

Damper remained in fixed position and gas valve changed.
Draft Observations of Fraser Burner No. 2

Draft in Air Ports.			Gas Pressure.			Furnace		
R.E.	Center.	L.E.	Main.	Top Burner.	Bottom Burner.	Draft.	Temp.	Remarks
1⅜	1⅜	1⅜	18	4	3½	.18	2205	(Working conditions.)
2¼	2¼	1¾	17	7½	6	.05	2255	(Gas added.)
2¼	2¼	1¾	16½	7	5¾	0	2235	(Too much added.)
1⅝	1⅝	1½	17	5½	3½	.10–.12	2270	(Working conditions. Gas reduced.)
1⅛	1¼	1¼	10	3	2½	.17	2165	(Working conditions.)

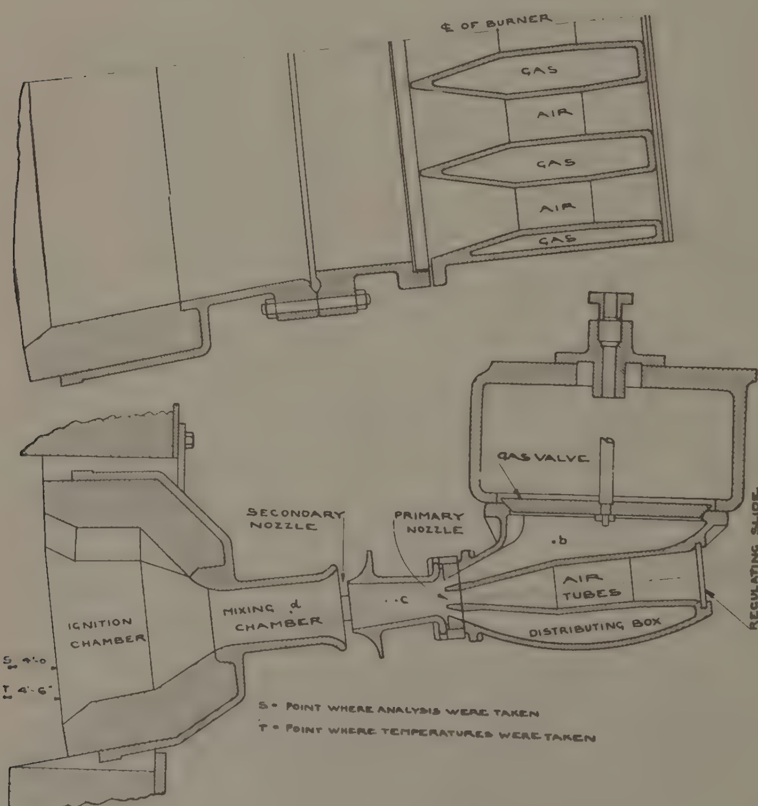
conclusion to be drawn from these experiments is that the Bradshaw Burner, supposedly proportioned with mathematical precision, shows no better efficiencies than the Fraser Burner, designed merely with the plain aspirating or injector principle in view, and proportioned by trial to efficiently operate with the pressure and volumes of gas available.

Observations of temperature were made from time to time in the combustion chamber of each boiler from #1 to #17, as per tables following. This was done by means of a Wanner Optical Pyrometer carefully cali-

		Combustion Chamber Temperatures.								Stack Temperatures.	
	Boiler	Series 1.		Series 2.		Series 3.		Series 4.			
	No.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Series 1.	Series 2.
Pipe Burner 1—5	1	2020	1980	2060	2090	2080	2140	2040	2020	565	640
	2	1975	2060	2050	2060	2140	1900	2150	2080	575	570
	3	....	....	2110	2090	2140	2100	....	....	515	580
	4	1980	1975	....	....	....	....	....	....	...	...
	5	2190	2160	2070	2175	1980	2090	2000	2135	555	560
Fraser #2	6	2160	2240	2230	2290	2080	2150	2290	2285	555	550
Fraser #1 7—11	7	2110	2230	2150	2140	2230	2095	2280	2200	595	560
	8	2240	2335	2195	2080	2170	2010	2160	2260	595	560
	9	2340	2260	2225	2265	2115	2125	2305	2270	595	550
	10	2080	2280	2050	2000	2140	2195	2200	2240	565	...
	11	2080	2240	2060	2140	2125	2225	2230	2100	625	...
Bradshaw	12	2200	2200	2230	2080	2230	2090	2260	2180	645	646
	13	2210	2160	2020	2080	2190	2220	2150	2260	595	...
	14	2160	2160	2075	2070	2250	2180	2170	2200	575	630
	15	2240	2175	2060	1950	2230	2115	2130	2140	575	...
	16	2190	2250	2130	2095	2230	2120	2300	2260	655	674
	17	2080	2200	2085	2135	2165	2190	2200	2220	605	...

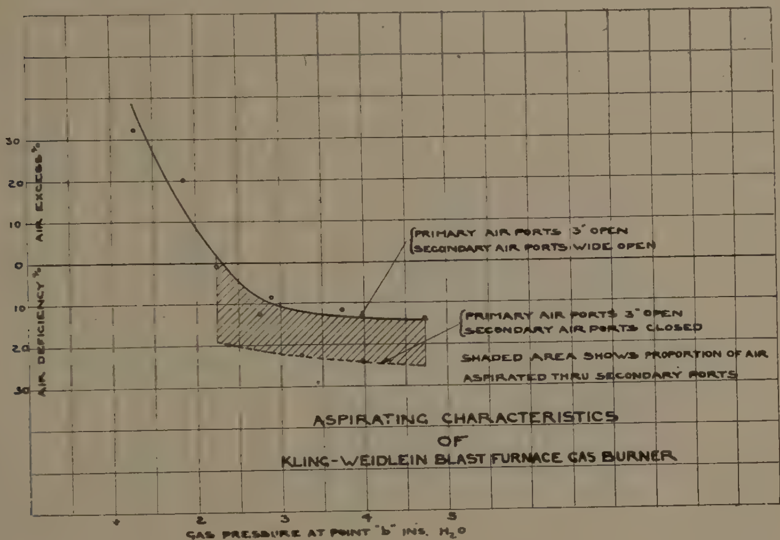
brated and then checked on the work against a standard couple in the furnace of one of the boilers. Two series of stack temperatures are also included.

These figures show that with the same amount of attention and the same pressure conditions throughout the house, the Pipe Burners (similar to Fig. 12), Fraser, and Bradshaw Burners produce about equal results. It might be added that this boiler equipment is kept in excellent condition, the settings being possibly not as tight as on the McKeesport boilers, but much superior to the average installation.



KLING - WEIDLEIN
BLAST FURNACE GAS BURNER FOR BOILERS
FIG. 18

A burner of the same general type is the Kling-Weidlein Blast Furnace Gas Burner for boilers, developed at the Ohio Works of the Carnegie Steel Company, and illustrated in Fig. 18.



The gas leaves the primary nozzle at high speed and in two streams, drawing the primary air in between the gas streams. The air mixes with the inside layers of the gas streams on their way to the ignition chamber, but before the latter is reached, the secondary air is drawn in in two streams and mixes with the outside layers of the gas stream.

The primary nozzle being machined, the gas is distributed uniformly over the entire width of the burner in thin but wide streams. The width on one stream is 3′ - 6″ and the total width of the four streams for one boiler (two burners) is 14 feet. The gas streams having the same speed and being of the same thickness throughout the entire width of the burner, draw the same amount of air at any point of the burner which insures a uniform mixture.

Results of a test run on this burner are enumerated on Table No. 8. The high stack temperatures and resulting low efficiencies are due to infrequent blowing off of the tubes as mentioned before in description of tests of the Birkholz-Terbeck burner at Ohio Works. The principal point investigated, in regard to this burner, was its aspirating characteristics, which have been plotted on a basis of gas pressures in distributing box. The full line curve is for regular operating port openings and shows good regulation between the comparatively narrow limits of 3″ to 5″ pressure, but a rapid rise in air excess below 3 inches. If the working pressure were to be from 3″ to 5″, it is probable that by a further opening of primary ports, this portion of the curve could be translated to a parallel position close to the zero line, thereby producing a condition close to the ideal over this particular range. The shaded portion shows the amount of air aspirated by the secondary ports, averaging from 10 to 15% of the total air required. In general these results show that within small limits of pressure variation the burner will aspirate practically, though not exactly, the correct quantities of air, but that for large pressure difference, regulation of gas pressure or air supply would have to be resorted to for the maintenance of maximum efficiencies.

Type 5—Burners through which all of the air is forced and completely mixed with the gas before the ignition point.

Due to our own failure to develop an aspirating burner of high capacity and to the lack of evidence that it had been accomplished elsewhere, the investigation of forced draft was the next logical step. The arrangement of burner is shown on Fig. 19. All the air required for combustion was supplied by a motor driven fan. Air enters the rectangular box at the back of the burner, and after passing through the short pipes, mixes with the gas. From the point where the air and gas

Table No. 8.

KLING-WEIDLEIN BURNER.

OHIO WORKS.

Summary of Tests.

With primary air ports open 3 inches and secondary ports wide open.

Pressures.		Drafts.					C. C. Analysis.			Stack Analysis.			Temps.		%	Air	Heat Balance.				
a Ins.	b Ins.	c Ins.	d Ins.	e Ins.	Stack Ins.	Air Tubes. Ins.	CO_2	O_2	CO	CO_2	O_2	CO	C. C.	Stack	Rating Developed.	Excess C. C.	Sens. Loss.	CO Loss.	Rad.	Eff.	Remarks.
1¾	1¼	.75	Pulsating	..	.26	.62	21.4	2.8	0.2	....	..	..	....	840	...	31.8	...	...	..	...	
2¾	2¼	1.00	.87	..	.20	.75	24.4	0.3	0.8	....	..	..	....	880	...	−1.0	...	...	..	...	
2⅞	1⅞	.50	.50	.10	.20	.50	22.7	2.0	0.2	17.0	7.0	0.0	2130	845	116	20.3	41.9	0.0	5.0	53.1	Gas Pulsating.
3½	2¾	.94	.94	Atm.	.12	1.00	24.4	0.0	2.8	23.6	0.6	0.8	2200	925	158	−12.9	34.1	4.1	5.0	56.8	O.K.
3¾	2⅞	.94	.94	Atm.	.12	1.00	24.0	0.0	1.6	23.4	1.4	0.3	2200	900	167	−7.9	33.9	1.6	5.0	59.5	O.K.
4⅞	3¾	1.12	1.06	Press. .06	.088	1.18	24.4	0.0	2.4	24.0	0.0	0.8	2200	960	184	−11.3	34.7	4.0	5.0	56.3	Too much Gas.
6	4¾	1.75	.88	Press. .10	.075	1.62	23.8	0.0	3.0	24.0	0.0	2.2	2200	1000	184	−14.1	34.6	10.5	5.0	49.9	Less Gas.
With primary air ports open 3 inches and secondary ports closed.																					
2¾	2⅝	1.25	.75	.06	...	1.12	23.2	0.0	4.2	22.0	0.0	3.2	2145	860	...	−19.7	...	...	..	...	
3½	3¼	1.50	1.37	.04	.137	1.31	23.6	0.0	5.0	22.8	0.1	4.2	2085	900	...	−22.3	...	...	..	...	
4½	4	2.00	1.12	.04	.088	2.00	23.2	0.0	5.4	22.3	0.1	5.6	2010	860	...	−24.7	...	...	..	...	

Blast Furnace Gas:		
	CO_2	13.1
	CO	26.4
	CH_4	0.3
	H_2	4.4
	B.T.U.	100.5
	At 220°	3.2
	Total	103.7

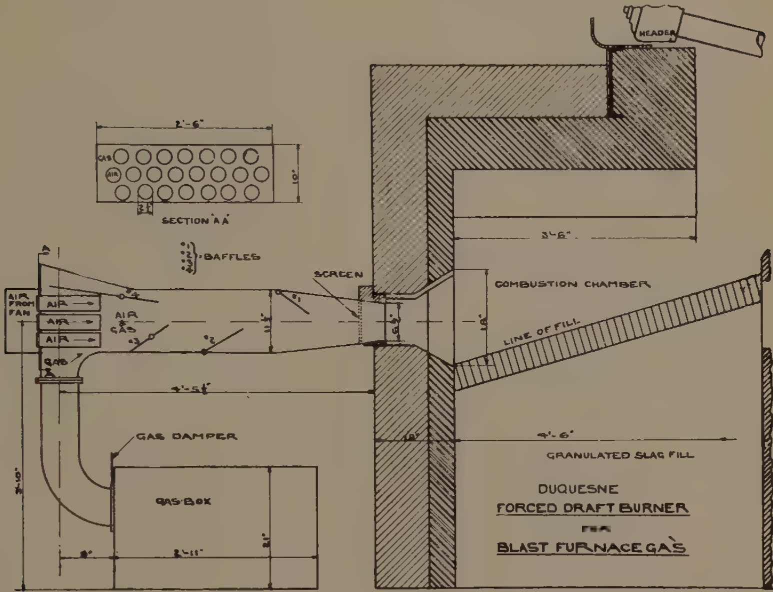


Fig. 19

meet, they travel together and become thoroughly intermingled before reaching the point of ignition, at the end of the burner. To supply the air theoretically required for complete combustion is purely a matter of speed of the fan, or control of the air by means of dampers. To thoroughly mix the air and gas is more difficult, but by careful regulation a burner efficiency of 96% was obtained. During the experiments the air supply was controlled by hand and the maintenance of good combustion required almost constant attention by the testing engineer due to rapid variations in the gas pressure even in the narrow limits of 5 to 7″. In a working arrangement of forced draft, the speed of motor or engine driving the fan should be controlled by gas pressure. By this method of positive air supply, a burner efficiency close to 100% may be maintained at any desired capacity.

Results of a representative test on the forced draft equipment on a 250 H.P., B. & W. Boiler follows:

Per cent. of Rating Developed		166
Furnace Gas Analysis	CO_2	14.7%
	CO	25.0
	H_2	3.1
Comb. Chamber Analysis	CO_2	24.6%
	O_2	.8
	CO	.8
Stack Gas Analysis	CO_2	21.9%
	O_2	3.1
	CO	...
Gas Pressure		2.5
Draft in Furnace		½" Pres.
Furnace Gas Temperature		35 °F
Comb. Chamber Temperature		2090
Stack Temperature		719
Calorific Value Fce. Gas / Cu. Ft		89.6%
Sensible Heat Fce. Gas / Cu. Ft		–05
Total Heat of Fce. Gas / Cu. Ft		89.1
Sensible Heat Lost in Stack		29.9%
Unconsumed CO Lost in Stack		0.0
Radiation (assumed)		3.5
Efficiency		65.6

Following are thirty 24-hour complete tests:

Remarks

Tests 12/14 to 12/18/14. (See page 405.)

The lower rate at which the boiler was run accounts for the lowering of the stack temperature.

The stack sample showing over 3 per cent. O_2 gives a much higher stack loss than would result were the boiler setting tight enough to allow a better balance of pressures and drafts in the boiler. When burning larger quantities of gas it was possible to overcome this draft (leakage) at the back of the boiler without requiring the stack damper being closed so tight as to raise the pressures in the front of the boiler too high.

Remarks

Tests 1/11 to 1/19/15. (See page 406.)

The stack temperatures increased slowly during the nine days the boiler was working. An explanation for this may be partly in the fact that the boiler had been off for several days and the large amount of flue dust and cinder had become cooled throughout. On tests 3/2 to 3/6 with the regular boiler setting there was also an increase in stack temperature during the week, but the difference between the temperatures at the beginning and end of the week is not so great as when the bottom of the boiler setting was filled.

Remarks

Tests 1/20 to 1/29/15. (See page 407.)

The principal item of note during the week was the increase of stack temperature, which was about 100° F. higher at the end of the week than at the beginning. These stack temperatures were carefully checked by using two couples in the stack—one being in the regular position near the boiler while the other was outside the boiler house 15 feet from the boiler (see sketch). These

OPERATION OF BOILERS WITH FORCED DRAFT.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 4. 250 H.P., B. & W. BOILERS.

Date		11/12 1914	11/13 1914	11/14 1914	11/16 1914
Boiler No.		11	11	11	11
Style of Burner and Fuel			Forced Draft. Setting. (Fig. 19). Filled Rough Gas.		
B.H.P. Developed		311	245	253	228
Per cent. of Rating Developed		125	98	101	91
Furnace Gas Analysis. (Dry)	CO_2	12.0	12.8	13.2	12.8
	CO	25.8	25.4	25.6	25.4
	H_2	3.6	3.6	3.4	3.6
Comb. Chamber Gas Analysis. (Dry)	CO_2	24.9	25.2	24.4	24.4
	O_2	0.3	0.4	0.7	0.8
	CO	3.1	2.5	1.7	1.0
3rd. Pass. Analysis. (Dry)	CO_2	25.2	24.2	22.0	..
	O_2	0.7	1.5	3.0	..
	CO	0.1	0.0	0.0	..
Stack Gas Analysis. (Dry)	CO_2	23.0	21.9	19.0	19.6
	O_2	3.1	3.3	5.6	4.7
	CO	0.0	0.0	0.0	0.0
Ratio Furnace Gas. (Dry) / C. C. Gas. (Wet)		1.46	1.49	1.61	1.62
Air Excess, 3rd. Pass., %		7.0	16.3	36.4	..
Ratio Furnace Gas. (Dry) / Stack Gas. (Wet)		1.74	1.85	2.16	2.06
Air Excess, Stack, %		34.4	39.4	78.6	63.2
Steam Pressure. Lbs		128	141	144	135
Gas Pressure, Ins. H_2O		2.7	2.5	2.5	2.5
Feed Water Temperature, °F		169	169	168	185
Furnace Gas Temperature, °F		410	410	360	330
Combustion Chamber Temp., °F		1990	1971	1945	1987
Stack Temperature, °F		800	770	741	698
Calorific Value of Gas, B.T.U		93.5	92.4	92.4	92.4
Sensible Heat in Gas, B.T.U		7.0	7.0	6.0	5.4
Total Heat in Gas, B.T.U		100.5	99.4	98.4	97.8
Stack Loss per Cu. Ft., B.T.U		16.3	15.4	14.6	13.7
Stack Loss per Cu. Ft. Fce. Gas, B.T.U		28.4	28.5	31.6	28.2
CO Loss per Cu. Ft. Fce. Gas, B.T.U		0.0	0.0	0.0	0.0
Stack Loss, %		28.4	28.7	32.1	28.8
CO Loss, %		0.0	0.0	0.0	0.0
Radiation Loss, %		3.5	3.5	3.5	3.5
Efficiency, %		68.1	67.8	64.4	67.7

OPERATION OF BOILERS WITH FORCED DRAFT.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 4. 250 H.P., B. & W. BOILERS.

Date		12/14 1914	12/15 1914	12/16 1914	12/17 1914	12/18 1914
Boiler No.		11	11	11	11	11
Style of Burner and Fuel		Forced Draft. (Fig. 19). Filled Setting. Clean Gas.				
B.H.P. Developed		415	422	411	415	386
Per cent. of Rating Developed		166	169	164	166	154
Furnace Gas Analysis. (Dry)	CO_2	14.7	14.6	14.4	14.7	15.4
	CO	24.8	24.7	24.5	25.0	23.6
	H_2	3.4	3.4	3.3	3.1	3.5
Comb. Chamber Gas Analysis. (Dry)	CO_2	24.4	24.7	24.7	24.6	24.7
	O_2	0.9	0.7	0.9	0.8	0.6
	CO	0.9	1.0	0.5	0.8	1.1
3rd. Pass. Analysis. (Dry)	CO_2	24.7	24.4	25.4	25.3	25.1
	O_2	0.8	1.4	0.5	0.7	1.1
	CO	0.0	0.0	0.0	0.0	0.0
Stack Gas Analysis. (Dry)	CO_2	21.6	21.5	21.3	21.9	21.1
	O_2	3.5	3.7	3.4	3.1	3.6
	CO	0.0	0.0	0.0	0.0	0.0
Ratio { Furnace Gas. (Dry) / C. C. Gas. (Wet) }		1.62	1.59	1.61	1.62	1.57
Air Excess, 3rd. Pass., %		9.1	16.1	5.4	7.8	12.6
Ratio { Furnace Gas. (Dry) / Stack Gas. (Wet) }		1.88	1.88	1.88	1.86	1.90
Air Excess, Stack, %		45.4	48.0	44.3	40.1	49.3
Steam Pressure, Lbs.		142	137	131	127	125
Gas Pressure, Ins., H_2O		1.4	1.4	1.2	1.2	1.2
Feed Water Tempeerature, °F		157	160	157	160	171
Furnace Gas Temperature, °F		40	39	38	35	37
Combustion Chamber Temp., °F		1998	2056	2063	2090	2065
Stack Temperature, °F		663	731	724	719	703
Calorific Value of Gas, B.T.U		89.8	89.4	88.8	89.6	86.2
Sensible Heat in Gas, B.T.U		–0.4	–0.4	–0.5	–0.5	–0.5
Total Heat in Gas, B.T.U		89.4	89.0	88.3	89.1	85.7
Stack Loss per Cu. Ft., B.T.U		14.7	14.5	14.3	14.3	13.8
Stack Loss per Cu. Ft. Fce. Gas, B.T.U		27.6	27.3	26.9	26.6	26.2
CO Loss per Cu. Ft. Fce. Gas, B.T.U		0.0	0.0	0.0	0.0	0.0
Stack Loss, %		30.9	30.7	30.5	29.9	30.6
CO Loss, %		0.0	0.0	0.0	0.0	0.0
Radiation Loss, %		3.5	3.5	3.5	3.5	3.5
Efficiency, %		65.6	65.8	66.0	65.6	65.9

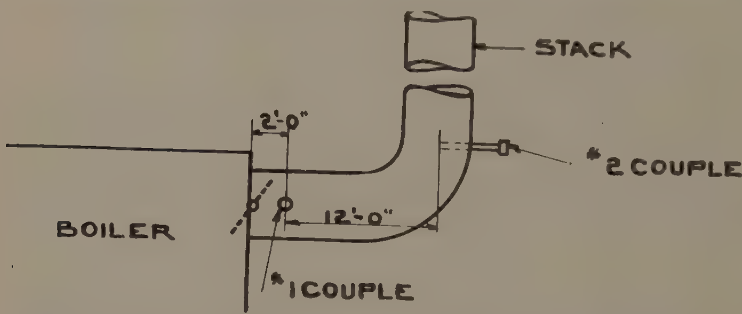
OPERATION OF BOILERS WITH FORCED DRAFT.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 4.—250 H.P., B. & W. BOILERS.

Date		1/11 1915	1/12 1915	1/13 1915	1/14 1915	1/16 1915	1/17 1915	1/18 1915	1/19 1915
Boiler No.		11	11	11	11	11	11	11	11
Style of Burner and Fuel		Forced	Draft.	(Fig. 19)	Filled	Setting.	Clean Gas.		
B.H.P. Developed		507	534	500	531	535	521	551	472
Per cent. of Rating Developed		203	214	200	212	214	208	220	189
Furnace Gas Analysis (Dry)	CO_2	14.4	14.4	13.7	14.6	14.2	14.3	13.4	14.0
	CO	24.7	24.5	25.4	24.1	24.9	24.8	24.5	24.2
	H_2	3.0	3.5	3.4	4.5	3.4	3.8	2.9	3.8
Comb. Chamber Gas Analysis (Dry)	CO_2	23.8	23.8	23.4	20.4	24.0	24.3	24.0	24.4
	O_2	0.9	1.1	2.5	2.5	0.6	0.6	0.7	0.7
	CO	1.7	1.2	0.7	5.3	2.3	1.9	1.6	1.7
3rd Pass Analysis (Dry)	CO_2	23.5	22.5	22.8	....	22.4	....	21.8	23.3
	O_2	1.7	2.6	2.2	....	2.0	....	3.2	2.2
	CO	0.0	0.1	0.2	....	0.4	....	0.1	0.3
Stack Gas Analysis (Dry)	CO_2	22.6	22.2	21.8	22.2	22.0	22.8	21.5	21.4
	O_2	2.2	2.5	3.0	2.6	2.5	2.6	3.1	3.2
	CO	0.5	0.0	0.0	0.2	0.4	0.1	0.2	0.3
Ratio { Furnace Gas (Dry) / C. C. Gas (Wet) }		1.59	1.62	1.69	1.57	1.44	1.55	1.54	1.52
Air Excess, 3rd Pass, %		20.4	31.9	24.8	....	21.8	....	40.4	24.3
Ratio { Furnace Gas (Dry) / Stack Gas (Wet) }		1.76	1.80	1.85	1.78	1.81	1.76	1.80	1.81
Air Excess, Stack, %		24.5	31.2	37.3	30.2	25.4	31.1	38.4	39.0
Steam Pressure, Lbs.		130	133	133	132	138	138	144	147
Gas Pressure, Ins. H_2O		1.6	1.4	1.2	1.8	1.6	1.6	1.6	1.6
Feed Water Temperature, °F.		135	151	155	151	166	166	157	170
Furnace Gas Temperature, °F.		47	46	46	50	50	52	51	51
Combustion Chamber Temperature, °F.		1945	1957	1913	1860	1843	1920	1930	1916
Stack Temperature, °F.		700	715	740	740	750	775	785	789
Calorific Value of Gas, B.T.U.		88.3	89.0	92.9	90.5	90.1	90.9	87.4	88.9
Sensible Heat in Gas, B.T.U.		–0.3	–0.3	–0.3	–0.2	–0.2	–0.2	–0.2	–0.2
Total Heat in Gas, B.T.U.		88.0	88.7	92.6	90.3	89.9	90.7	87.2	88.7
Stack Loss per Cu. Ft., B.T.U.		13.9	14.2	14.8	14.8	15.0	15.6	15.7	15.7
Stack Loss per Cu. Ft. Fce. Gas, B.T.U.		24.4	25.6	27.4	26.4	27.2	27.4	28.3	28.4
CO Loss per Cu. Ft. Fce. Gas, B.T.U.		2.8	0.0	0.0	1.1	2.1	0.6	1.2	1.7
Stack Loss, %		27.8	28.8	29.6	29.2	30.2	30.3	32.4	32.0
CO Loss, %		3.2	0.0	0.0	1.3	2.3	0.6	1.3	2.0
Radiation Loss, %		3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Efficiency %		65.5	67.7	66.9	66.0	64.0	65.6	62.8	62.5

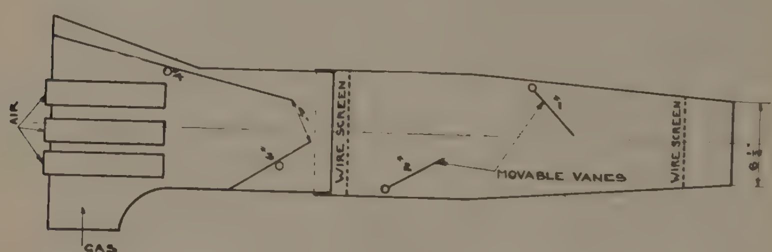
OPERATION OF BOILERS WITH FORCED DRAFT.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 4.—250 H. P., B & W. BOILERS.

Date		1/20 1915	1/21 1915	1/22 1915	1/25 1915	1/26 1915	1/27 1915	1/28 1915	1/29 1915
Boiler No.		11	11	11	11	11	11	11	11
Style of Burner and Fuel		Forced	Draft.	(Fig. 19)	Filled	Setting.	Clean Gas.		
B.H.P. Developed		455	436	448	445	468	452	468	465
Per cent. of Rating Developed		182	174	179	182	187	181	187	186
Furnace Gas Analysis (Dry)	CO_2	13.5	14.7	14.5	14.3	14.4	14.6	14.7	14.0
	CO	25.1	24.1	24.6	24.8	24.5	23.5	25.2	25.2
	H_2	3.0	3.2	3.4	3.7	3.4	3.9	2.9	2.3
Comb. Chamber Gas Analysis (Dry)	CO_2	24.6	24.5	24.0	24.7	24.2	24.6	24.4	24.4
	O_2	0.8	0.8	1.0	0.8	1.0	0.9	1.0	0.7
	CO	0.8	0.5	0.4	1.4	0.6	0.9	0.5	0.5
3rd Pass Analysis (Dry)	CO_2	24.9	24.9	24.6	24.9	24.4	24.8	24.9	25.0
	O_2	0.7	0.6	0.6	0.4	0.8	0.7	0.6	0.5
	CO	0.4	0.2	0.2	0.4	0.3	0.4	0.2	0.3
Stack Gas Analysis (Dry)	CO_2	23.4	23.3	23.6	23.9	23.3	23.9	23.8	23.9
	O_2	1.9	1.9	2.1	1.2	1.5	1.3	1.4	1.1
	CO	0.1	0.0	0.1	0.3	0.2	0.3	0.0	0.1
Ratio { Furnace Gas (Dry) / C. C. Gas (Wet) }		1.58	1.61	1.66	1.56	1.63	1.55	1.67	1.64
Air Excess, 3rd Pass, %		5.4	5.6	5.6	2.0	7.3	5.5	5.7	4.1
Ratio { Furnace Gas (Dry) / Stack Gas (Wet) }		1.69	1.71	1.70	1.67	1.70	1.62	1.78	1.68
Air Excess, Stack, %		21.6	23.2	24.2	11.5	16.6	18.7	16.8	12.9
Steam Pressure, Lbs		139	139	147	143	140	146	139	130
Gas Pressure, Ins. H_2O		1.4	1.4	1.75	1.75	1.75	1.75	1.75	1.75
Feed Water Temperature, °F		168	168	151	149	141	155	155	158
Furnace Gas Temperature, °F		49	48	46	45	44	48	45	39
Combustion Chamber Temeperature, °F		1998	2025	2012	1986	2010	2008	2012	2018
Stack Temperature, °F		772	804	821	808	829	844	855	888
Calorific Value of Gas, B.T.U		89.3	86.9	89.1	90.7	89.1	86.8	89.5	87.9
Sensible Heat in Gas, B.T.U		–0.2	–0.2	–0.3	–0.3	–0.3	–0.2	–0.3	–0.4
Total Heat in Gas, B.T.U		89.1	86.7	88.8	90.4	89.8	86.6	89.2	87.5
Stack Loss per Cu. Ft., B.T.U		15.7	16.4	16.8	16.5	17.0	17.4	17.6	18.4
Stack Loss per Cu. Ft. Fce. Gas, B.T.U		26.5	28.0	28.6	27.6	28.9	28.2	31.3	30.9
CO Loss per Cu. Ft. Fce. Gas, B.T.U		0.5	0.0	0.5	1.6	1.1	1.6	0.0	0.4
Stack Loss, %		29.8	32.3	32.2	30.6	32.2	32.6	35.1	35.3
CO Loss, %		0.6	0.0	0.6	1.8	1.2	1.8	0.0	0.5
Radiation Loss, %		3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Efficiency, %		66.1	64.2	63.7	64.1	63.1	62.1	61.4	60.7

two couples showed exactly the same temperatures on the chart during the three days they were run together.



Before starting on 1/20/15, baffle #3 (see sketch below) was placed in the burner. Baffles #1, 2 and 4 could be adjusted from the outside of the burner but #3 could not be moved. During the tests on and following 1/20/15, baffles #3 and #4 were in the position shown below. Baffles #1 and #2 had no effect on the mixture.



Remarks

On 2/26 were obtained some of the best samples taken during the tests. For example:

Combustion Chamber.......	CO_2	24.8%	O_2	0.6%	CO	0.4%
Last Pass..................	"	25.4%	"	0.4%	"	0.2%
Stack	"	24.0%	"	1.6%	"	0.0%

In a tighter boiler this 24.0% of CO_2 in the stack could have been maintained, but due to too much blowing out of gases around doors, the stack damper was opened more and kept that way during the remainder of the week. This allowed a considerable leakage of

OPERATION OF BOILERS WITH FORCED DRAFT.
DUQUESNE BLAST FURNACE BOILER HOUSE NO. 4.—250 H. P., B. & W. BOILERS.

Date		2/15 1915	2/16 1915	2/17 1915	2/18 1915	2/19 1915
Boiler No.		11	11	11	11	11
Style of Burner and Fuel		Forced Draft. Rough Gas.		(Fig. 19).	Filled	Setting.
B.H.P. Developed		455	464	452	448	449
Per cent. of Rating Developed		182	185	181	179	179
Furnace Gas Analysis (Dry)	CO_2	15.1	13.0	15.0	14.8	12.6
	CO	24.3	25.1	24.3	24.7	25.1
	H_2	3.5	3.0	3.3	3.2	3.0
Comb. Chamber Gas Analysis (Dry)	CO_2	24.6	24.3	24.5	24.3	24.3
	O_2	0.6	0.6	0.5	0.4	0.3
	CO	0.9	0.7	0.7	1.2	1.1
3rd Pass Analysis (Dry)	CO_2	25.0	25.4	25.0	24.9	25.0
	O_2	0.5	0.4	0.4	0.6	0.5
	CO	0.3	0.3	0.2	0.3	0.3
Stack Gas Analysis (Dry)	CO_2	24.5	24.2	22.8	23.0	22.9
	O_2	0.8	1.4	2.6	2.3	2.4
	CO	0.3	0.2	0.0	0.0	0.0
Ratio $\left\{\begin{array}{l}\text{Furnace Gas (Dry)}\\\text{C. C. Gas (Wet)}\end{array}\right\}$		1.67	1.69	1.68	1.67	1.59
Air Excess, 3rd Pass, %		3.8	2.9	3.4	5.1	3.7
Ratio $\left\{\begin{array}{l}\text{Furnace Gas (Dry)}\\\text{Stack Gas (Wet)}\end{array}\right\}$		1.72	1.73	1.86	1.84	1.78
Air Excess, Stack, %		7.4	15.0	32.5	28.4	28.2
Steam Pressure, Lbs.		160	151	149	150	155
Gas Pressure, Ins. H_2O		4.2	4.2	4.5	4.2	4.2
Feed Water Temperature, °F.		158	161	160	172	177
Furnace Gas Temperature, °F.		330	334	315	330	332
Combustion Chamber Temperature, °F.		1960	2000	2010	2025	2050
Stack Temperature, °F.		803	830	865	850	880
Calorific Value of Gas, B.T.U.		88.4	89.7	88.0	88.9	89.7
Sensible Heat in Gas, B.T.U.		5.5	5.6	5.1	5.5	5.6
Total Heat in Gas, B.T.U.		93.9	95.3	93.1	94.4	95.3
Stack Loss per Cu. Ft., B.T.U.		16.5	16.6	17.8	17.5	18.0
Stack Loss per Cu. Ft. Fce. Gas, B.T.U.		28.4	28.7	33.1	32.2	32.0
CO Loss per Cu. Ft. Fce. Gas, B.T.U.		1.6	1.1	0.0	0.0	0.0
Stack Loss, %		30.4	30.1	35.5	34.2	33.6
CO Loss, %		1.7	1.1	0.0	0.0	0.0
Radiation Loss, %		3.5	3.5	3.5	3.5	3.5
Efficiency, %		64.4	65.3	61.0	62.3	62.9

air, which accounts for the CO_2 in the stack gases dropping off about 1%.

In general, the conditions throughout the week were good.

SUMMARY OF BOILER TESTS.

Plant.	Boiler.	% Rating Developed.	Burner.	No. Tests.	Efficiency. Max.	Min.	Avge
Duquesne[1]	250 H.P. B. &.W.	150	Common	28	59.4	35.9	50.9
Duquesne[2]	"	108	Aspirating Fig. 13.	7	65.9	57.8	61.6
Duquesne[2]	"	175	Forced draft Fig. 18	30	68.1	60.7	64.6
McKeesport[3]	500 H.P. B. & W.	155	Common Fig. 9	3	75.0	70.0	72.3
So. Chicago	325 H.P. Rust	114	Common	23	69.3	52.1	58.3
So. Chicago	"	114	Birkholz-Terbeck	22	66.2	61.0	64.6
So. Chicago	360 H.P. Stirling	122	Common	8	63.4	55.0	59.4
So. Chicago	"	122	Birkholz-Terbeck	20	70.6	58.4	64.5
So. Chicago	355 H.P. Wheeler	122	"	4	62.7	58.6	60.3
Ohio Works[4] Youngstown	400 H.P. Stirling	125	Ohio Works Fig. 12	18	60.5	45.2	51.5
Youngstown	"	130	Birkholz-Terbeck	19	67.0	41.0	53.8
Wisconsin[5]	350 H.P. Stirling	130	Common	3	67.0	59.2	61.9
Wisconsin	"	127	Birkholz-Terbeck	3	71.4	68.4	69.7
Monessen[6]	500 H.P. Stirling	—	Fraser	4	67.5	61.7	65.4
Monessen[6]	"	—	Bradshaw	4	67.5	62.7	65.1

[1] Lower average than present operation.
[2] Boiler not in particularly good condition.
[3] Best cond. of setting and baffles found during investigations.
[4] Both burners given the same amount of attention.
[5] Boilers in good condition. Max. test on common burner is comparative to average of Birkholz Terbeck.
[6] Boilers in good condition. Fraser burner handled more gas than Bradshaw.

In general these results are for test conditions. For average operation the efficiency would probably be about 5% less.

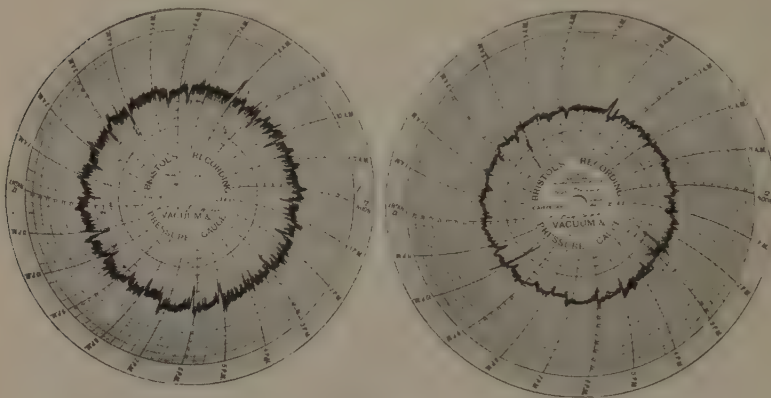
The boiler on which these tests were conducted had an old and leaky setting, thereby rendering difficult the reduction of excess air in the stack, and baffles which were not absolutely tight although in fair condition. With nearly perfect proportions of air and gas admitted through the burners as shown by analysis of the gas in the combustion chamber, and the stack draft effective at this point, the stack gas analysis showed an average

of 100% air excess. In order to eliminate this air, pressure was carried throughout the boiler by closing the stack damper, the extra work of driving the products of combustion through the boiler being supplied by the fan. Adjustments were then made to give zero pressures at the top of the last pass, with the result that the air excess was decreased to an average of 25%, with most of this air leaking in around the stack breeching, at which point it had no effect on the boiler efficiency. The greater the quantities of gas burned, the greater the ease of maintaining furnace pressure and eliminating leakage, so that the stack losses remained nearly constant at about 30% over a wide range of capacity.

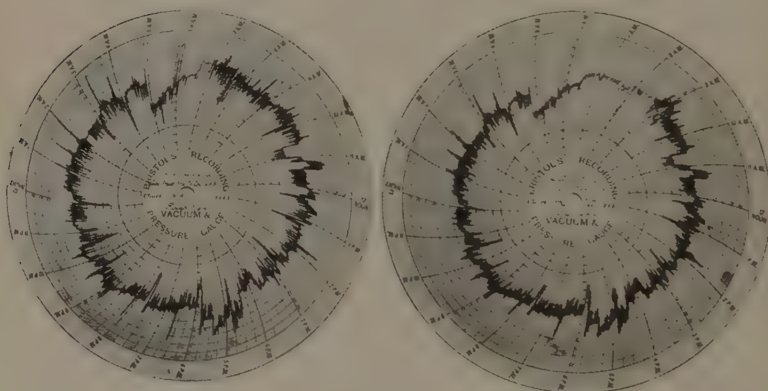
Remarks

The most noticeable feature in the comparison of boiler tests with relation to burners, is that in the same plant, nearly all of the burners compared show very little difference in efficiency, although there may be considerable difference between the tests in the various plants. The plant must be considered a constant therefore, and we must conclude that the equipment and supervision is superior in the plant showing the best results. The difficulty of comparison is thus evident. The following deductions may be drawn from the data and personal observation.

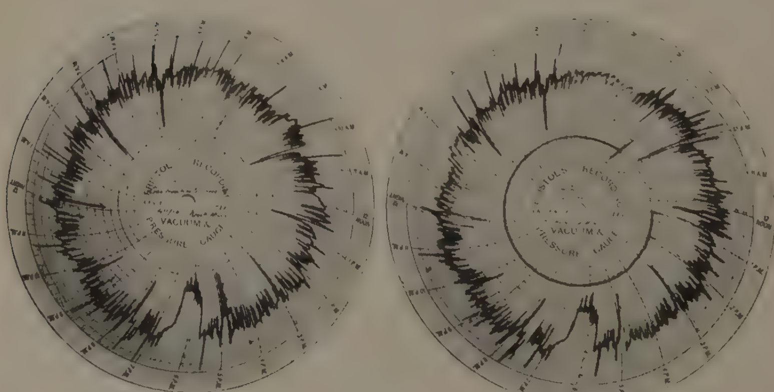
The charts (Figs. 20, 21 and 22) show the frequency and range of variations in the gas pressure both at the boilers and in the main lines. Fig. 20 shows variations with clean gas of from 4″ to 6″ at the boiler and from 8″ to 10″ at the gas cleaning plant on the discharge side of the fan. Fig. 21 shows pressure variations with rough gas of from 8″ to 12″ at the boiler and from 6″ to 11″ in the rough gas main. Fig. 22 shows about the same variations in the rough gas main and in the boiler, which, in this case, takes gas directly from the dust-catcher. The variations shown by these charts even during any one hour indicate the impossibility of making any given



Clean Main. Fig. 20. Boiler



Rough Main. Fig. 21. Boiler.



Rough Main. Fig. 22. Boiler.

adjustment of damper to induce a proper amount of air to suit the constantly fluctuating gas volumes admitted to the boiler.

BOILER CONCLUSIONS.

The foregoing boiler data seems to indicate

First—That under test conditions all types of burners reviewed seemed to approximate equal results with the same equipment and management, although engineering features in some types render manipulation and control easier.

Second—That when the equipment is propertly designed and in first class condition much higher efficiencies prevail.

Third—That combustion chambers should be sufficiently large to accomplish full combustion before the gas passes the first row of tubes. Chambers should be proportioned to suit burner conditions. The common burner with the large combustion chamber at McKeesport, the Bradshaw and Fraser burners at Monessen, and the Bradshaw at Cambria Steel Company show the advantages of large combustion chambers. The forced draft burner at Duquesne with an extremely small chamber but with good burner efficiency show that under this condition a large combustion chamber would be unnecessary. The combustion chamber in the Wheeler Boiler at South Chicago was so small as to make the use of the common burner prohibitive, while the Birkholz-Terbeck could be operated under the same condition and show 40% more boiler capacity and 15% efficiency gain. In general, the size of combustion chamber should be inversely proportional to the degree of mixing in the burner.

Fourth—That balanced draft control in the combustion chamber and necessary damper regulations with consequent exclusion of infiltrated air are a decided advantage.

Fifth—That although a burner can be designed to aspirate the proper quantity of air at one pressure none have yet been designed to aspirate over any very considerable range of varying gas pressures. Over small ranges a number of the burners recently developed approach within practical limits the condition of sufficient air supply.

Sixth—That gas pressure constantly varying within relatively wide limits render impossible the attainment of good combustion without constant regulation of air supply.

Seventh—That unless pre-heaters, super-heaters, or economizers, are used, efficiencies of over 70 to 72% should be cautiously accepted.

Eighth—That constant gas analysis and intelligent supervision is one of the principal factors in obtaining continuous good efficiency and control without very much change in equipment.

Ninth—That a properly designed burner with easy means of controlling air and gas mixtures is far preferable to the slip-shod methods prevailing in many plants.

Apparatus and Observations.

The form of testing herein described as Duquesne tests might better be termed "Burner Tests" or "Combustion Tests" rather than "Boiler Tests," since the object is an investigation primarily, of burners and combustion, and secondarily, of boiler design and heat absorption. It might be interesting to mention the apparatus and methods used.

An integrating Hallwachs Steam Meter was used to determine the output of the boiler. This instrument, when maintained in first class condition throughout, gives consistent and satisfactory results, but when not so maintained, may give very misleading, if not startling, figures.

Analyses of blast furnace gas were made in the steel works laboratory according to United States Steel Cor-

poration standards. The average analysis for the year 1914 at Duquesne Furnaces is:

CO_2	12.9%
CO	26.3
H_2	3.7
CH_4	0.0
N_2	57.1
B.T.U.	92.1

Methane is tested for but has not been found in blast furnace gas at Duquesne.

Analyses of the products of combustion were made in the field using an Orsat-Lunge Apparatus with four bubbling pipettes, one with potassium hydroxide solution for the CO_2, one with stick phosphorus for O_2, and two with cuprous chloride solution for CO. Too much emphasis cannot be placed on the extreme care that should be exercised in the determination of CO. Experience has conclusively demonstrated that in order to obtain reliable results, two pipettes must be used, the solutions frequently changed, and generous amounts of strip copper placed in the solutions. In view of the fact that 1% of CO in a flue gas, containing 18% CO_2, adds approximately 6.5% to the losses, and a proportionately larger amount in more dilute gases, it becomes apparent that a high degree of accuracy in the CO determination is very desirable. For this reason, efficiencies based on analyes of a CO_2 recorder, are not dependable.

For a study of combustion, samples of burnt gases should be drawn from the combustion chamber and the different passes. In all positions where the temperature is above 900° F., water cooled sampling tubes must be used to prevent the dissociation of carbon dioxide which occurs when the gas is in contact with an incandescent body containing iron or carbon.

Temperatures in the stack were taken with a platinum couple encased in a metallic protecting tube. In the combustion chamber and other high temperature points a long brass tube was used. This tube is water cooled and extends to within nine inches of the hot

junction of the couple, a ½″ diameter silica tube covering the projecting wires. The cooling effect extends along the silica tube not more than one inch, insuring correct temperatures at the hot junction. With this arrangement a 30″ couple may be extended by copper wire for use in a water cooled tube of any desired length, the connection being in the cooled portion of the tube and a constant cold junction temperature maintained by the circulating water. This instrument may remain for indefinite periods of time in the highest temperatures encountered in boiler and stove work, without injury to the expensive platinum couple and without attention other than an infrequent replacement of the small silica tube. To maintain a constant cold junction temperature of the stack pyrometer, a small water cooled end is used in connection with the metallic protecting tube.

Continuous records of temperature in boiler and stack were obtained by connecting the various couples to a six-point Hartmann and Braun Recorder. The installation of a pyrometer in the combustion chamber of each boiler, with a multiple recorder, would supply a simple, yet highly satisfactory, means of maintaining a good state of combustion throughout the boiler plant.

Pyrometers inserted in the boiler passes, for observations of flue gas temperatures, should never be placed between or near the boiler tubes, as a very considerable error may be introduced by the influence of the comparatively cool tubes. For this reason, it is never advisable to assume as stack temperatures, the indications taken between the tubes of the last pass of the boiler, since the results thus obtained are invariably lower than the correct figure.

For draft readings, an Ellison Differential Draft Gauge was used and for temperatures of air and gas, ordinary thermometers, read at frequent intervals.

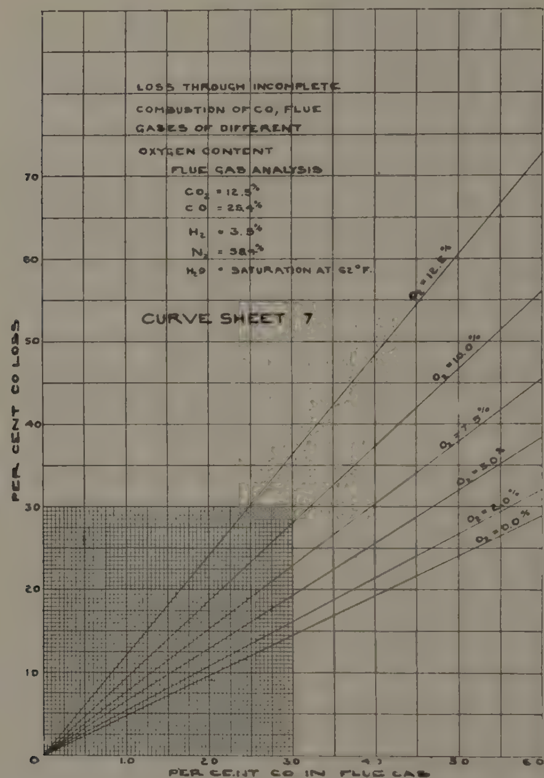
It might be well to mention here that much experimental work that has been done in this field is of questionable accuracy owing to the use of unsuitable in-

struments, improper use of suitable instruments, or questionable methods of calculation. Recently numerous test results have been published in connection with new burners for which high efficiencies have been claimed. Since some of these results have been based upon indications of CO_2 recorders and flue gas temperatures and the heat balance calculated accordingly, it might be well before going further to call attention to the errors that might result in data obtained in this manner, if extreme care is not exercised by those making the test.

While a CO_2 recorder can be made to correctly indicate the quantity of CO_2 present in a flue gas, it does not indicate the other constituents—O_2 and CO—the record of which is necessary for any calculation of efficiency. Where such an instrument in conjunction with a pyrometer, is used for controlling purposes, the method of operation is to regulate the air supply to the furnace until a maximum quantity of CO_2 and a reasonably low temperature in the flue gas is indicated. Such indications can be very misleading for the reason that an indication of CO_2 alone is a measure of the stack loss only when the flue gases are not accompanied by other burnable constituents. Of course, in practice, even with the so-called mixing burners, a perfect flue gas is an exception and not a rule; hence a calculation of the stack loss based only on records of CO_2 and temperature is more or less erroneous. The magnitude of such errors for any quantity of CO present in any flue gas can be got from the curves shown on curve sheet 7.

The importance of maintaining a constant, low, temperature on the cold junction of a pyrometer couple may be illustrated by the following example:

A Le-Chatelier couple was calibrated in an electric furnace over a range of 200 to 800° F., and found to be 20° low over the entire range. This couple, placed in boiler stacks so that the cold junction extended 12″ outside the stack shell, was found to read 110° low at temperatures of 550° and 85° low at temperatures of 650° F.

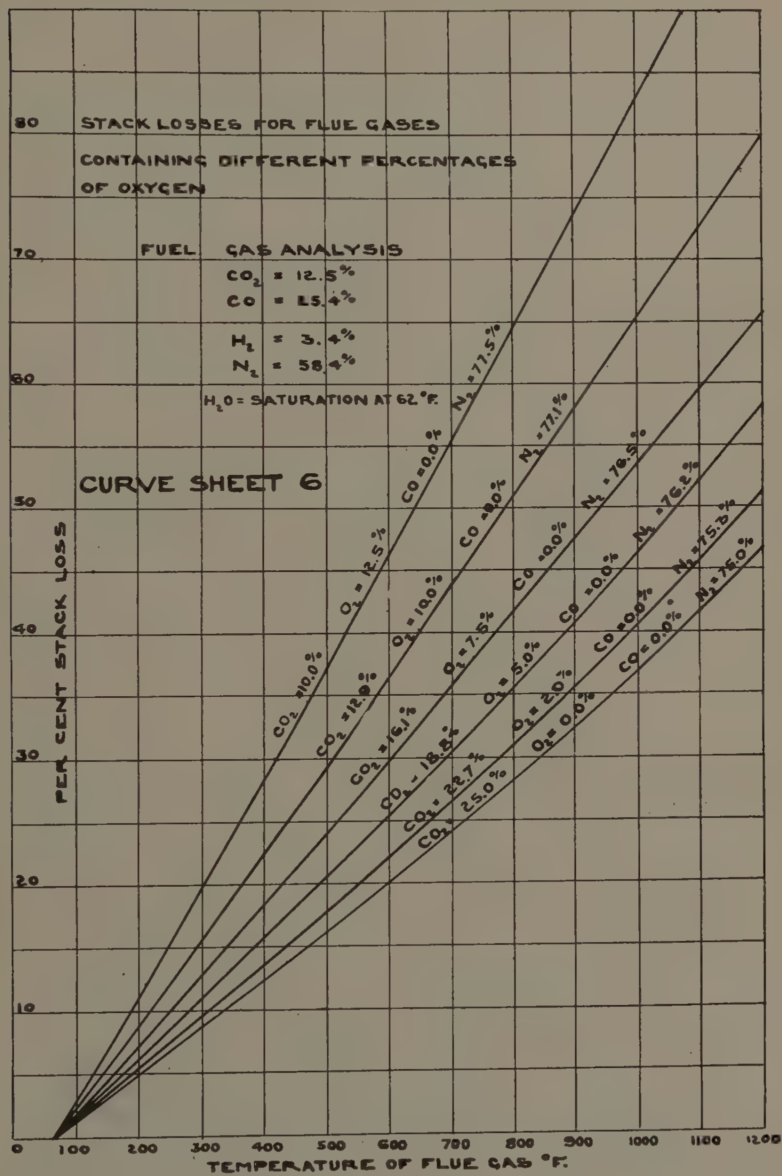


This error was due entirely to the fact that the cold junction was not cooled, its rise in temperature, above the standard point, being produced by heat conduction through its metallic protecting tube and by radiation from the stack shell.

The magnitude of an error of 85° in the temperature of the flue gases may also be observed on Curve Sheet 6.

General Calculations.

Introductory to the discussion of general calculations, it should be noted that the volumetric method is used throughout, in contrast to the usual, but much slower and bulkier, method of reducing gas quantities to weights. The basis of heat input is taken as the



calorific value of one cu. ft. of dry blast furnace gas at 62° F.

The volume of the products of combustion at any point in the operation is to the volume of furnace gas

as their total percentages of carbon gas constituents. The following calculation illustrates the method:

Assume:

Blast Furnace Gas (Dry).		*Flue Gas (Wet).*	
CO_2	15.1%	CO_2	22.5%
CO	24.3	O_2	0.7
H_2	3.5	CO	0.3
N_2	57.2	N_2	68.2
Total C Gases	39.4	H_2O	8.3
B.T.U.	88.4	Total C Gases	22.8
Temperature	330.0	Temperature	803.0

Calorific heat in furnace gas........ = 88.4 B.T.U. per cu. ft.
Sensible heat in " " @ 330° = 5.5 " " " "

Total................. = 93.9 " " " "
Sensible heat in flue gas at 803°...... = 16.5 " " " "

$$\text{Flue gas per cu. ft. of furnace gas} = \frac{39.4}{22.8} = 1.73 \text{ cu. ft.}$$

Heat loss per cu. ft. of furnace gas = 1.73 x 16.5 = 28.5 B.T.U.
CO " " " " " " " = .003 x 1.73 x 324 = 1.70 B.T.U.

$$\text{Sensible heat loss} = \frac{28.5}{93.9} = 30.4\%$$

$$\text{CO loss} \ldots\ldots\ldots\ldots = \frac{1.70}{93.9} = 1.8$$

Radiation loss.......... = 3.5
Efficiency .... = 64.3

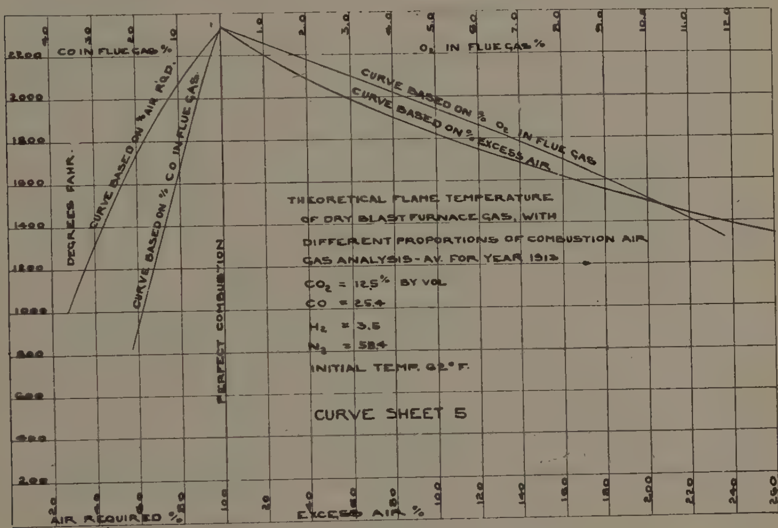
The steam in flue gas is the sum of the amount formed by burning hydrogen and the moisture content of the furnace gas. A large number of determinations gives an average figure for the latter of about 35 grains per cu. ft. of rough gas.

In the calculation of calorific heats, the net values are used; for CO—324, and for H_2—278 B.T.U. per cu. ft. at 62° F. and 30″ Hg.

For the calculation of sensible heat in furnace and flue gas, the specific heat formulæ given in Richard's "Metallurgical Calculations," Vol. 1, were used. The heat lost in flue gas is assumed to be that amount contained between 62° F. and the flue temperature. It has not been considered necessary to go into detail of correcting for moisture and sensible heat in the air.

As an aid to making, rapidly, approximate calculations of efficiency by the indirect method, the following

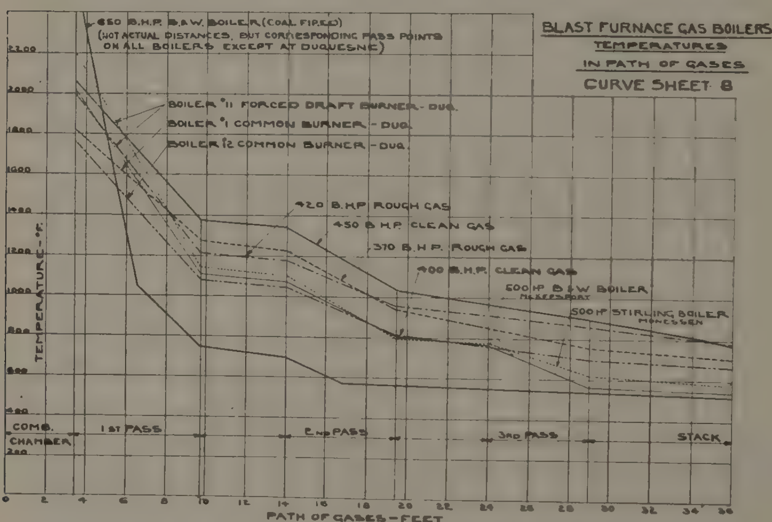
curves have been plotted: Curve Sheet 5 showing theoretical flame temperature of blast furnace gas with different proportions of air excess and unconsumed CO; Curve Sheet 6, showing sensible heat losses in stack for gases of various analyses and temperatures; Curve Sheet 7, showing the losses due to unconsumed CO in the stack gases, for various percentages of CO in the stack gas analyses and different degrees of dilution.



General Observations.

While conducting boiler tests, primarily designed to study burner construction, it has been found difficult to separate the main question from the allied subject of heat absorption in boilers burning blast furnace gas. This investigation was made by placing a water cooled pyrometer successively at the top and bottom of each pass, the general condition meanwhile being held constant by means of pyrometers in the combustion chamber and stack. Results of such observations on several 250 H.P., B. & W. Boilers at Duquesne, a 500 H.P., B. & W. Boiler at National Tube Company, McKeesport, and a 500 H.P. Stirling Boiler at Pittsburgh Steel Company

at Monessen, are shown on Curve Sheet 8. These curves show the desirability of high flame temperature, which results in a large proportion of the total absorption taking place in the first pass at a temperature range where rate of heat transfer is greatest. The McKeesport and Monessen Curves, by their sharp drop in the third pass, demonstrates the great advantage due to exceptionally tight baffling.



In the taking of the temperatures in the different parts of the boiler, the areas were explored with the couple to find the highest temperature in order to make sure that no cooling influences in any way would affect the readings.

Operations with efficiencies over 70% are rare, and while this may be done on occasions, extremely few can maintain it as an operating condition.

It is possible that in the case of first class equipment throughout, boiler plants could be run at the very highest efficiency if a corps of engineers with testing equipment were continuously regulating each boiler. This, however, would not be a commercial proposition.

Hence, automatic or equivalent means of continuous regulation should be striven for.

Of a total of 60 Blast Furnaces in the Corporation under observance, the tests and information from the operators indicate a practice of not exceeding 55%. The increase of 10% probably possible with improved conditions will show a yearly saving of one and one-half million dollars.

In a number of instances operators stated that their efficiency was high, due to changes of equipment and operation, and pointed to less coal consumed as the final proof. In some instances, after the changes were made, the total steam capacity was only normal for the quantity of iron produced. The only deduction to be formed is that the former efficiency was extremely low and the plants are now only operating in the proximity of where they should have been previously. A change of equipment is in almost every instance accompanied by extensive repairs and one is often misled as to the real reason for the improvement.

GENERAL CONCLUSIONS.

Both the tests on boilers and stoves on the preceding pages, as mentioned before, are for the most part of combined efficiency, and a comparison of a burner in one plant with that in another under different conditions and supervision is not fair. In some cases, opportunities of testing two or more types gave indication of what might be expected, and it is best for those interested to study the data collected and apply it to their own conditions.

The indirect boiler test is not to be trusted except in the hands of experienced engineers. Low stack temperatures alone mean very little, without the corresponding flue gas taken at the same point. Erroneous temperatures can be obtained in various ways, principally as follows:

1st—By placing the thermometer or couple too near the tubes or drums.

2d —By not placing the instrument in the gas flow, as in an eddy spot or two near the wall, too near the damper, etc.

3d—By having air leaks around the couple.

4th—Excess infiltration of air in the boiler or stack continuous.

It will be observed, from the information collected, and here presented, that the subject of properly burning gas is of more complex character than it first appears, and this is further borne out by the fact that almost every plant of importance is at present either reviewing or experimenting with a burner of their own development. A few of the most prominent ones are outlined and descriptions of many others have been received, but without sufficient data to warrant their inclusion. All, however, come within the subdivision outlined.

The data were collected and presented with a twofold object: First, to exhibit in a comprehensive manner the present status of stove and boiler combustion development, with a general collection of sufficient data and tests, in conjunction with the opinions obtained from the different plant engineers, as well as numerous instances of combined check data obtained for verification purposes, for the guidance of those who wish to pursue the subject to a further extent; second, to call attention to the fact of the economic waste prevalent in most of our large installations due to lack of observation and attention to what was and still is in some cases, a minor by-product and of secondary consideration.

I wish to express my gratitude to Messrs. Siebert and Fitzgerald, of the Experimental Engineering Department of the Duquesne Works, for their aid in testing, and in checking and preparing this paper. Further, I wish to especially call attention of the Institute to the kindness and courtesy of the various managements of not only the plants quoted, but of many others to whom I applied for information. The invariable answer, "We will give you

everything we have,'' expresses most forcibly the change of attitude between manufacturers within the last few years, and demonstrates a mutual desire for more extensive information. Too much credit cannot be given the Iron and Steel Institute for its share in the accomplishment of this result, and if this paper fulfills no other purpose, the efforts expended in its collection are not in vain, if it emphasizes the further recognition of the spirit of co-operative educational advancement in the iron and steel industry.

MODERN METHODS OF BURNING BLAST FURNACE GAS IN STOVES AND BOILERS

DISCUSSION BY HENRY P. HOWLAND
Superintendent of Blast Furnaces, Wisconsin Steel Company, South Chicago, Ill.

The title of Mr. Diehl's paper covers a subject peculiarly difficult, due to the fact that its consideration is comparatively new and that reliable information is very hard to obtain. In reading the paper one is impressed with the thoroughness and fairness with which the paper has been written. One is further impressed with the fact that there are a great many different gas burners and that many of them do fairly good work.

A year ago at the Wisconsin Steel Company we attempted to increase the efficiency of our gas-fired equipment. Thus far we have installed three pressure burners on our stoves and sixty-six Birkholz-Terbeck burners at our boilers. Our first step in approaching this problem was the installation of checkers in the bottom 25 ft. of the combustion chamber of No. 1 stove. This increased the stove efficiency, but impeded the flow of gas to such an extent that we were unable to use the stove to its full capacity. The next move was the equipping of No. 2 stove with a pressure burner. The air for this burner was supplied through an 18-in. pipe by a No. 9 Sturtevant fan. Having all other air inlets closed we were now able to compel the stove to burn all the gas desired. This type of burner had been expected to effect quite a gas saving by increased stove efficiency. In this we were disappointed.

SAVING OF GAS NOT EFFECTED BY BURNER ALONE.

After several tests of stoves equipped with and without this burner, we were forced to conclude that with

equipment such as ours, namely, stoves with large checker openings, small total heating surface relative to radiating surface and poorly insulated shells, the burner in itself will not effect any gas saving. The per cent. of radiation and stack loss remained practically the same. On these stoves the radiation loss per stove increases practically in the same proportion as the work done by the stove. That is, the total radiation loss on the stove system is practically the same regardless of the number of stoves in use. This may be explained on the ground that the increased pressure in the stove as created by the pressure burner tends to raise the shell temperature. Whether this condition would be true in the case of well insulated shells, we had no way of ascertaining.

In the endeavor to cut down the increased radiation and stack loss, due to forcing the stove by the use of the pressure burner, checkers were installed in the combustion chamber of No. 2 stove. Supported on arches located about 6 ft. above the bottom of the combustion chamber, these checkers extend 57 ft. to the top of the chamber. They are built with 9-in. openings and 4½-in. wall, adding 3,800 sq. ft. to the heating surface of the stove. When the pressure burner was now used on this stove, both the stack and radiation loss was found to have been reduced to a marked degree resulting in greatly increasing the stove efficiency. By equipping No. 1 and No. 5 stoves in the same manner, we were able to operate with three stoves. The net result is as follows:

October, 1914—Five stoves in use burning 21,000 cu. ft of gas per minute and heating the blast (36,000 cu. ft. of air per minute) to 1,100 degrees Fahrenheit.

September, 1915—Three stoves in operation using 16,000 cu. ft. of gas and delivering the same total blast heat.

How large a quantity of gas one of these burners will burn completely has not been determined. With the gas-main pressure as high as 10 in., we were able to force 9,500 cu. ft. of gas per minute through the checker-

obstructed combustion chamber and burn it completely. Under these conditions, the pressure in the combustion chamber was 3½ in. and at the chimney valve about ¼ in.

Burner Regulation.

This burner lends itself easily to correct regulation. The gas and air mains are equipped with U tubes and regulating valves. The pressures necessary to give complete combustion are ascertained. With the pressure at the required points, the stove tender not only is assured of the required heat, but that the quantity of air supplied is correct. During the past year we have analyzed our stack gases day and night, and find that generally the pressure burner is giving a gas with less than 1 per cent. of either carbon monoxide or oxygen which, compared to our former practice, would be called "complete combustion."

The power required to deliver the air to these burners will, of course, depend upon many local conditions. Delivering 9,000 cu. ft. of air per minute at 20-in. pressure requiring two No. 9 Sturtevant fans, the power consumed is, approximately, 45 kw. On the basis of a production of 500 tons per day and ½ cent per kilowatt hour, the power cost thus amounts to 1 cent per ton of iron.

Eliminating the Combustion Chamber.

You have seen that we accomplished the desired gas saving by using the checkers in the combustion chamber in connection with the pressure burner. Due to their location, these checkers are four times as efficient per square foot of heating surface as the original checkers. We have three stoves equipped with the pressure burner, in which the combustion chamber has been practically eliminated. This method of construction has possibilities which may be of value in designing future stoves.

In order to increase the amount of gas passing through the pressure burners, it is necessary to increase the gas-main pressure. The advisability of this practice

is doubtful from the standpoint of efficient furnace operation, since it seriously increases the pressure on top of the furnace. We would propose that instead of using the furnace to create this increased pressure, a booster be located in the gas main. The same result could probably be obtained by using an exhauster on the chimney side of the stove. This latter suggestion offers possibly a simpler operating proposition, more especially in view of the probability that with new stoves of proper design, stack heats may be so low as to interfere with the chimney draft.

Hand Regulation of Burner Desirable.

Turning to the problem of boiler burners, we find ourselves inclined to more enthusiasm in favor of some such burner as the Birkholz-Terbeck type than that expressed by the author of the paper. This burner provides an easy, convenient hand regulation of the proper amounts of air and gas for complete combustion, and a mixing chamber for the air and gas before entering the boiler setting. The author has, in our opinion, placed too much emphasis upon variation in boiler house gas-main pressure. At most plants there is no great variation in this pressure from hour to hour or day to day. Consequently, if a ready means for hand regulation is provided and stack gas regularly analyzed there is no reason why reasonably high efficiencies cannot be attained by boiler house operatives.

In the case of the "Common burners," as termed by the author, which are in most general use at the present time, no means is provided for the boiler house superintendency to manipulate or regulate the gas and air mixture, and it is therefore fruitless to provide them with means of analyzing the stack gases.

However, when it comes to comparing by a test the new and old burner, it is always possible, as suggested by Mr. Diehl, to stick in "a brick or a ball of clay" thereby getting approximately the correct regulation and

bring up the efficiency of the old burner much above the regular and usual practice.

Boiler Plant Efficiency with Burners.

Mr. Diehl places the average efficiency of the furnace boiler plant using the "common burner" at "not over 50 per cent. and frequently much lower." We had an excellent opportunity to test nine of our boilers equipped with thirty-six Birkholz-Terbeck burners. Only one furnace being in operation, we carefully measured the gas to the stoves and boiler house, and accurately figured the gas produced by the furnace thus checking our gas input. The feed water and gas was measured for a period of 8 hours. The burners were not touched by any one—in other words—it was a regular operating condition. The result was 68 per cent. efficiency. We believe this represents a big improvement over our practice on these same boilers equipped with the common burner.

We would conclude as follows: For use on stoves we believe the pressure burner to be preferable. Regarding boiler burners, first, the point of automatic regulation, as emphasized by Mr. Diehl, does not seem to us to be vitally essential; second, it should be admitted by all that a big step in advance has been taken in equipping a boiler house with burners capable of easy hand regulation in the place of the so-called "common burner." (Applause.)

President Gary: The discussion will be continued by Mr. A. E. Maccoun, of the Carnegie Steel Company.

MODERN METHODS OF BURNING BLAST FURNACE GAS IN STOVES AND BOILERS

Discussion by A. E. Maccoun
Superintendent, Edgar Thomson Blast Furnaces, Carnegie Steel Company, Braddock, Pa.

Mr. Diehl has covered his subject of burning blast furnace gas in stoves and boilers very thoroughly, and has given us details of the various methods in use. As he has pointed out, it was impossible to develop and arrive at an efficient gas burner for this purpose before the use of clean gas under uniform conditions of pressure, moisture, etc., was introduced. The cleaning of blast furnace gas has given the blast furnace operator these conditions, and since its introduction many refinements in the construction of gas burners have been made, and still further refinements will be made in the future to obtain the maximum efficiency possible under our different conditions. We must not lose sight of the fact that in conjunction with any burner the design of stoves or boilers must be adapted to burning blast furnace gas if we are to obtain the best results.

Nearly all burners described are modifications with improvements in details of the old Bunson or Spearman type of burner. The efficiency of all these burners depends on the thorough pre-mixing of the proper proportions of air and gas, so as to obtain more nearly perfect combustion. This, on some of the newest types of burners, approximates 98%. With the old type of Spearman burner used on the stove test which I outlined in my paper on "Blast Furnace Advancement" before the Iron & Steel Institute in May, 1915, an average stove efficiency of 61% was shown; but I called attention in this paper that the gas in the combustion chamber burned progressively in vertical layers, that the

samples above the burner always showed poorer combustion than at the burner level, and that combustion was not complete until the gases had passed out of the combustion chamber into the dome of the stove. By burner refinements, as described by Mr. Diehl, these conditions were greatly improved, and various long tests made on this same stove under the same operating conditions showed an increase in stove efficiency, the average of these tests showing an efficiency of 71%. This improvement was all due to better mixing of gas at the burner and the use of a burner design that eliminated the burning of gas explosively and the throwing out of flame around the burner.

There are three principal methods of mixing gas used by the various burners described.

First, the velocity mixing type.

Second, the vane mixing type.

Third, the type which mixes by impinging air and gas streams into each other.

Efficient gas burners can be constructed by the use of each of these principles, and as Mr. Diehl has shown, there is no type which has been developed at the present time that we may safely say is the most efficient burner. We may only decide which type of burner is the most efficient after thorough and reliable tests, for at the present time the various types of gas burners have not been tried out long enough in practice, and sufficient detailed tests have not been made, to arrive at any such conclusion.

This paper brings to your attention the various developments being made in the different methods of burning blast furnace gas. We can still look for further improvements to be made along these lines in the future. (Applause.)

President Gary: The discussion is open now to any others. We will be glad to hear from any one.

Mr. Willis L. King: Every time that I come to these meetings I am more and more impressed with the excel-

lence of the papers and the thanks we owe to these young men for their time and knowledge and scientific research. The committee in charge of the program cannot, of course, be expected to know every one in the Institute who perhaps would be very glad to give such a paper, and I would suggest, Mr. Chairman, that those members of the Institute who are willing and capable of presenting papers that would be of general use to this Institute, would inform the committee to that effect, and I have no doubt that in the course of time, as the meetings go on, they will have a chance to be heard. I am sure that I enjoy these papers. Although I am not technical, I feel that they are of great use, and I hope there will be no disposition on the part of the members to fail in giving their best thought and scientific knowledge to the Institute. (Applause.)

President Gary: We shall now have a paper on The Heat Treatment of Steel in Automatic Electric Furnaces, by Mr. Thaddeus F. Baily, of Alliance, Ohio.

THE HEAT-TREATMENT OF STEEL IN AUTOMATIC ELECTRIC FURNACES

Thaddeus F. Baily

President, The Electric Furnace Company of America, Alliance, Ohio

Since the earliest time of which we have record of the use of steel, heat-treatment for the purpose of increasing its physical properties has been carried on in connection with the materials for war purposes; but until the advent of motor-car production in commercial quantities, heat-treatment of steel in commercial work was little practised excepting in the treatment of tools.

The strains developed in motor-car operation, however, demanded material of greater strength and resilience than that offered by common steels, and new alloy steels showing remarkable physical properties were rapidly produced in commercial quantities. It soon developed that even these new steels must be heat-treated in a proper way as determined by their composition, in order to get reliable results in their use. It was at this time that heat-treatment of steels in large quantities became acknowledged as an essential operation in the manufacture of all steel parts subject to severe strain. It is thus to be noted that although the advantages of heat-treatment were known from the earliest time, this knowledge was not put into extensive commercial practice until the success of a great industry depended upon the application of this knowledge.

The Problem of Heat Treatment.

The problem that immediately confronted the users of heat-treated steel was the lack of uniformity shown in its physical properties, and this for any given steel was immediately traced to the imperfections of the means employed, as heat-treatment at first was done in some crude

form of combustion furnace, either oil, gas or coal fired. Coupled with the imperfections of the heat-treating furnace itself was the inadequate means for quenching the material after heating for the purpose of hardening, and it soon became known that for a given steel the quenching temperature, the time in the quench, the quenching liquid and its temperature were all factors of importance affecting the physical properties of the steel under treatment. Another, and one of the most uncontrollable variables, was the human element, to which all the other variables were more or less inseparably tied.

The problem in heat-treatment, then, becomes one where, if results possible of attainment with any particular steel are to be realized and engineering calculations based on these figures, the treatment must be carried on in such equipments and by such methods that the chance of any variation in the essential features of the treatment must be reduced so as to preclude the possibility of the material passing through the heat-treating equipment without receiving the treatment intended.

It has been possible to control automatically to some extent the temperature of oil or gas furnaces, but no device has yet been designed which has proved itself dependable. Even assuming perfect control of temperature, there is yet required means for automatically removing the material from such controlled furnace, quenching it quickly in a quenching medium of constant temperature for a definite length of time, removing it from the bath and charging it into the second or drawing furnace, which must also be of constant temperature. Even assuming that the temperature of the furnaces can be kept constant by some automatic fuel-control means, and that suitable means may be developed for handling the material through the various operations just cited, there is in this general scheme the fatal weakness that the furnace temperature and the temperature of the material under treatment may vary greatly and the whole scheme from a practical standpoint break down on this feature.

Automatic Control of Heat and Material Attained.

With the development of electric furnaces for heat-treating, it became apparent that the temperature of such a furnace could be readily maintained within a few degrees of the designated temperature whether standing idle or running at any predetermined capacity. This type of furnace, then, so far as temperature control was concerned, was all that could be desired; but the human element involved in the operations of drawing the charge when heated, quenching and recharging still remained, and in response to a demand for a heat-treating equipment of the automatic type where the human element would consist solely in the placing of the material on the charging platform of the first furnace—all subsequent operations being done automatically in accordance with the predetermined adjustment—the equipment now to be described was developed. One of such equipments has operated continuously over periods of more than 3,000 hours, in which time more than 8,000 tons of steel were treated with a temperature variation of less than 10 degrees Fahr. in the metal; and a uniformity of results in the physical properties of the material treated were obtained which indicate that the small variations noted in the tests one with another were due solely to the slight variations in the composition of the steel.

The Equipment and Its Operation.

A typical equipment embracing all the features required to perform automatically the essential operations in heat-treating, consists of an electric furnace of the continuous type in which the material under treatment is moved through the furnace on cast beams of suitable shape and composition by means of hydraulic pushers; a transfer and quenching device hydraulically operated is adapted to reach into the furnace immediately after

the opening of the doors; then a charge of heated material is pushed on to this transfer platform by the pusher at the opposite end of the furnace. When this material has reached a central position on the transfer platform it is withdrawn from the furnace and plunged into the quenching bath. The downward movement of the transfer opens the valve on the quenching medium supply line, which supply is maintained under a constant head and temperature. The transfer platform with its material remains in the quench, and the cold quenching medium is allowed to flow unrestricted until a time element device actuates the hydraulic valve on the lift cylinder of the transfer, whereupon the transfer platform with the material is raised out of the quench and placed on the charging platform of the second or drawing furnace, where it remains at rest until moved into the second furnace by the pusher on that furnace. Simultaneously with the movement of the material into the second furnace, the heated material is pushed out of the discharge end.

The important element in the operation of the entire equipment is the temperature measuring devices adapted to take the temperature of the material under treatment itself, not the furnace temperature, and when the material has reached the designated temperature these special pyrometers actuate the interlocked electrically operated hydraulic valves on the valve pulpit controlling the cylinders performing the various motions of the equipment.

It will thus be seen that the material cannot be removed from the first furnace until it has reached the prescribed temperature, at which time it is quickly removed and quenched for a definite period in a liquid of constant temperature, after which it is put into the drawing furnace and subsequently withdrawn upon reaching the designated temperature for the drawing operation. When the material under treatment is delivered at the discharge end of the second furnace it can have had no other treatment than that for which the equipment is adjusted.

Such equipments as the one just described produce materials whose physical properties are increased to the full extent of the theoretical possibilities of heat-treatment. And this is accomplished with a marked reduction in labor and usually at a lower net cost for treatment than by hand-operated fuel-fired furnaces. (Applause.)

PRESIDENT GARY: I believe this subject is of very great interest and importance, and I am glad to know that it is going to be discussed to some extent. Mr. Samuel T. Wellman, of Cleveland, will speak, and Professor J. W. Richards, of Lehigh University, has written a short statement which the secretary will read, and after that open discussion will be offered. Mr. Wellman. (Applause.)

HEAT TREAMENT OF STEEL IN AUTOMATIC ELECTRIC FURNACES

Discussion by Samuel T. Wellman
Chairman, Wellman-Seaver-Morgan Company, Cleveland, Ohio

When our secretary asked me to discuss this paper, I declined at first. I thought he would do much better to have the paper discussed by these live wires who are right in the business, and not come to an old has-been like me. However, I am very glad to say a few words. I won't take much of your time.

In the first place, I want to congratulate Mr. Baily on the beautiful way in which his paper has been presented. If we had more of our papers illustrated in such a way as this, it would add enormously to the interest.

There is no question but that an electrically-heated furnace such as described by Mr. Baily is ideal in every respect. The electrical timing and regulation can be worked out without any trouble; and if the cost of the electrical heating is not very much in excess of coal or gas, it should have a very extensive field.

In the heat treatment of steel, especially alloy steels, it is of the greatest importance that the treatment should be exactly alike in every piece of steel. If occasionally a piece goes through without proper treatment, it is, of course, an occasion of weakness in whatever machine it is used; and if failure follows, the damage to the reputation of the maker of the steel cannot be measured in dollars and cents. Any steel maker can make some steel of the highest quality; no steel maker can make it always perfect. The one that comes the nearest to the 100 per cent. mark is the one that gets the best of the trade.

What the steel maker wants and needs is apparatus

that is fool-proof. Mr. Bailey's scheme for heat-treating, if properly designed and built, should come very near this much desired end.

If this invention of Mr. Baily's could be successfully applied to heating furnaces or soaking pits for hot steel ingots, it would have a wide field to work in. There is room for great improvement over existing practice. The present furnaces have always seemed to me very crude and an immense amount of heat is lost. I believe that an electrical furnace, somewhat on Mr. Baily's design, can be made that will beat the ordinary gas furnace in cost of operation.

I am very glad to congratulate Mr. Baily in his success so far and hope he may do much better in the future.

The only suggestion that I would make, after seeing Mr. Baily's pictures of the furnace—and this is all that I know about it, I have never seen the drawings of the apparatus—I may be wrong, but I judge that the furnace is electrically heated. But I would suggest that a simpler apparatus, a simpler way of making the movements, would be to make them all electrical. Many years ago I went through much the same experience that Mr. Baily has had in working out the charging machine. The first one was all hydraulic, and the next one was hydraulic and electric, and the next one was all electric. Now nobody thinks of anything else but an all-electrically operated and regulated charging machine. In these days of the perfection of electrical motors and regulators, when you simply push a button and have a magnetic controller that does any work you like, the problem is very much simpler than it was in the old days when we simply had a controller by which we pushed a lever. That whole cycle of preparation, it seems to me, could be very much simplified by making all the movements entirely electrical, and it don't need any argument before you gentlemen, to say that in this day in this country of zero weather for two or three months in the year,

the less hydraulic we can have around the works, the better off we are and the more peace of mind we will have at night. (Applause.)

President Gary: Some of the most prominent has-beens are the most effective and the most necessary "isers." Mr. Wellman cannot relegate himself to the past. Behold him reading his paper without the use of glasses! (Applause.) Listen now to Professor J. W. Richards speaking through the tongue of our secretary.

(Secretary reads Professor Richards' MS.)

HEAT TREATMENT OF STEEL IN AUTOMATIC ELECTRIC FURNACES

DISCUSSION BY J. W. RICHARDS

Professor of Metallurgy, Lehigh University, South Bethlehem, Pa.

Mr. Baily has opened up a method with a wide range of possible usefulness. The automatic heat treatment, eliminating the personal factor of the workman, is a great step in advance in the heat treatment of steel.

With proper design and heat insulation, electric furnaces of the Baily type should be capable of putting into the articles to be treated fifty per cent. of the heating energy of the current. This heating energy is theoretically 635 kilogram Calories (2,515 B.T.U.) per h.p. hour, or 860 kg. Calories (3,410 B.T.U.) per kw. hour. Taking the data per kw. hour, 430 Calories (1,705 B.T.U.) will raise a considerable amount of steel to the quenching temperature, as may be seen from the heat required to raise steel to different temperatures given in the following table:

Raising to		Heat required		Weight heated	
		Cal. per kg.	B.T.U. per lb.	Kg. per Kw. hr.	Lb. per Kw. hr.
600°C	1112°F	85.0	153.0	10.1	22.2
700°C	1292°F	111.8	201.4	7.7	16.9
800°C	1472°F	135.8	244.4	6.3	13.9
900°C	1652°F	152.8	275.0	5.6	12.3
1000°C	1832°F	167.8	302.0	5.1	11.2
1100°C	2012°F	183.0	329.4	4.7	10.3
1200°C	2192°F	200.0	360.0	4.3	9.3

At places where electric power is expensive, it should be practical to arrange the furnace to burn coal, gas or oil for preliminary heating to within one or two hundred degrees of the quenching temperature, and then use the electric heating only for completing the heating and adjusting the final quenching temperature. Such a

combined fuel and electric furnace might work cheaper in many localities than an all-electric furnace. In fact, if gas or oil is available, it would seem quite simple to introduce some fuel heating in Mr. Baily's electric furnace itself, and thus diminish the power consumption where current was expensive.

There seems no doubt that some such device would improve rolling practice, by discharging ingots from the furnace always at the proper temperature. The electric furnace could then act as an electrically-controlled soaking pit, which would receive hot ingots and discharge them only at the properly adjusted temperature. A furnace of the pusher type, with electrically-controlled discharging device, would achieve this end. The heating might be all-electric, or part electric and part gas, or even all-gas.

President Gary: Are there others who wish to speak on this subject?

Mr. Allerton S. Cushman: Mr. Chairman, I would like to ask the author something about the adjustment of pyrometers whereby the temperature of the metal is maintained and not the temperature of the furnace. The author referred to that point having been covered. I would like to have him explain just how those pyrometers are arranged.

Mr. Baily: That is arranged by having the pyrometer coupled within perhaps half an inch of the material about to be discharged, so that the influence comes almost solely from the metal instead of from the furnace temperature. Does that answer the question?

Mr. Cushman: It does in a measure, but when we are heat-treating large steel objects, it is necessary that the heat should soak all the way through the metal so that the refinement would be complete. And Professor Richards' suggestion that we might have an automatical

control seems almost utopian, because the surface temperature of a large piece of steel is not always necessarily the temperature of the center, and the important thing in the pyrometer measurement of large steel pieces in furnaces is to be sure that the center of your piece is thoroughly refined, to the same extent that the surface is.

Mr. Baily: In answer to that I will say that we allow a sufficient length of time in the heating up operation that the material has had adequate time to come to a temperature equilibrium. In the case shown on the screen, it allowed us four hours in coming to that temperature, so that there would be a very slight variance.

President Gary: Are there others? Everything connected with electricity is intensely interesting. Where does it commence, and where will it leave off? What is it going to do? It will encircle the globe. Touch a button and it will do almost anything in a mill. Go into some of these large mills now and you are astonished at the lack of men distributed around the mill. As in olden times, you see the machinery all in operation, and it is a wonder how the machinery can be operated without the use of men. Electrical welding, electrical finishing of steel, it may be expensive at the present time, it may be utopian to suppose that the method will be economical, will be cheap; but that is what we said with reference to propulsion by electricity not long ago. All the railroad people supposed they couldn't use electricity in moving an engine or a train. But in all respects the use of electricity is more and more wonderful day by day, and this is one of the greatest and most interesting and most important subjects for consideration by manufacturers at the present time. And I have no doubt that every one here is interested, and all who have gone would have been interested if they could have heard this paper, and will be interested in reading it. At the next meeting I suppose perhaps some professor in some of the great

colleges may, at the right moment, touch a button, and we will sit here and listen to a machine talking to us about some electrical device or prospect. And so the world is moving along, it is simply magic. (Applause.)

MR. BAILY: Mr. Chairman, I would like to answer Dr. Richards' comment on furnace efficiencies. He mentioned that furnace efficiencies of 50 per cent. should be obtained. On the furnace shown on the screen, it showed, on official test, a thermal efficiency of 92½ per cent. (Applause.)

PRESIDENT GARY: Just because I have a moment's time, I want to say that at this meeting, as in all other meetings, I am peculiarly struck with the fact that the papers show a disposition on the part of all the members of the Institute to be cordial in their reception of others who are seeking information and who are asking to go into the recesses of the mills, the offices, examine the figures, to get at the facts, for the purpose of building up an argument or an illustration which shall be of benefit to the members of the whole association. It must be a delight to every member of this Institute to know that he comes into an atmosphere of the greatest friendship and the greatest cordiality when he attends the meetings. I venture the assertion that there has never before been an institute, an association of any kind, in any country, that showed a better feeling or a better disposition, or that carried on its work on a higher plane, or that was doing more to build up the things of the country which are needed and which ought to be built up. And I congratulate myself that I am a member of the Institute, and that I have the high privilege of coming into communication with such men as we meet twice a year.

The Secretary has some announcements to make.

Whereupon Secretary McCleary made certain announcements, and the meeting was adjourned until two o'clock P. M.

GENERAL PRINCIPLES OF THE CONTROL OF PIPING AND SEGREGATION IN STEEL INGOTS

Henry M. Howe

Professor of Metallurgy, Columbia University, New York City

This paper explains the more important elementary principles by means of which piping and segregation in steel ingots may be lessened. Many of these principles I have verified by means of direct unpublished experiments. Yet the subject is so complex that I may have overlooked others. Hence my inferences are provisional, and subject to control by direct tests.

Piping.

The reason why the axial cavity or pipe forms is that during the latter part of the solidification the inner parts of the ingot are contracting faster than the outer parts. The relative rates of contraction of the outer and inner parts therefore govern the whole matter. These rates of contraction represent roughly the corresponding rates of cooling, and it is by studying these rates of cooling that we can best understand the matter.

When a mass of molten steel is poured into a cold metallic mould, its skin begins cooling very rapidly by the escape of its heat into the mould walls, whereas the cooling of the interior is much slower, because the heat that escapes thence must pass chiefly through the still hot outer walls of the ingot. As soon as a continuous outer crust has formed on the top as well as the sides, two parts may be recognized, the outer and *solid parts*, containing what we may call a *cave*, still filled with molten steel.

During the early part of the solidification, because the outer parts are cooling faster than the molten interior, the dimensions which they tend to give the cave are smaller than the volume of the metal which that cave has

to contain, quite as when a hot tire is shrunk on a wheel the dimensions which it tends to give the space within it are less than those of the wheel. Because the molten within the cave, like the wheel within the tire, is incompressible, it resists the natural contraction of its walls and in effect stretches them in the sense in which the wheel stretches the tire, preventing it at every degree of temperature in the cooling from contracting to the natural dimensions which it would have reached if unopposed.

But this cooling of the outer parts cannot continue indefinitely to be faster than that of the interior, because, both starting at the same temperature, say 1500°, and cooling to the same temperature, say 0°C, have the same temperature range to pass through, and towards the end of their cooling, when the centre has sunk to say 100°, the outer parts are but little cooler than the central ones. Hence because the outer parts cool faster than the inner at first, they must needs cool less rapidly than the inner parts later on, and at some moment in between the rate of cooling of the outer and of the central parts must be identical. We may call this the *neutral moment*, and the periods which precede and follow it the pre-neutral and the post-neutral ones, respectively. During the whole of the pre-neutral period, because the contraction of the outer parts tends to be more rapid than that of the central ones, the outer parts are being stretched by the resistance of the slower cooling central parts, but this rate of stretch decreases continuously till, at the neutral moment, it becomes zero. At this moment, as at every preceding one, the dimensions of the cave exactly fit those of the molten, because the molten in resisting the pressure of the walls of the cave has stretched them out to its own volume.

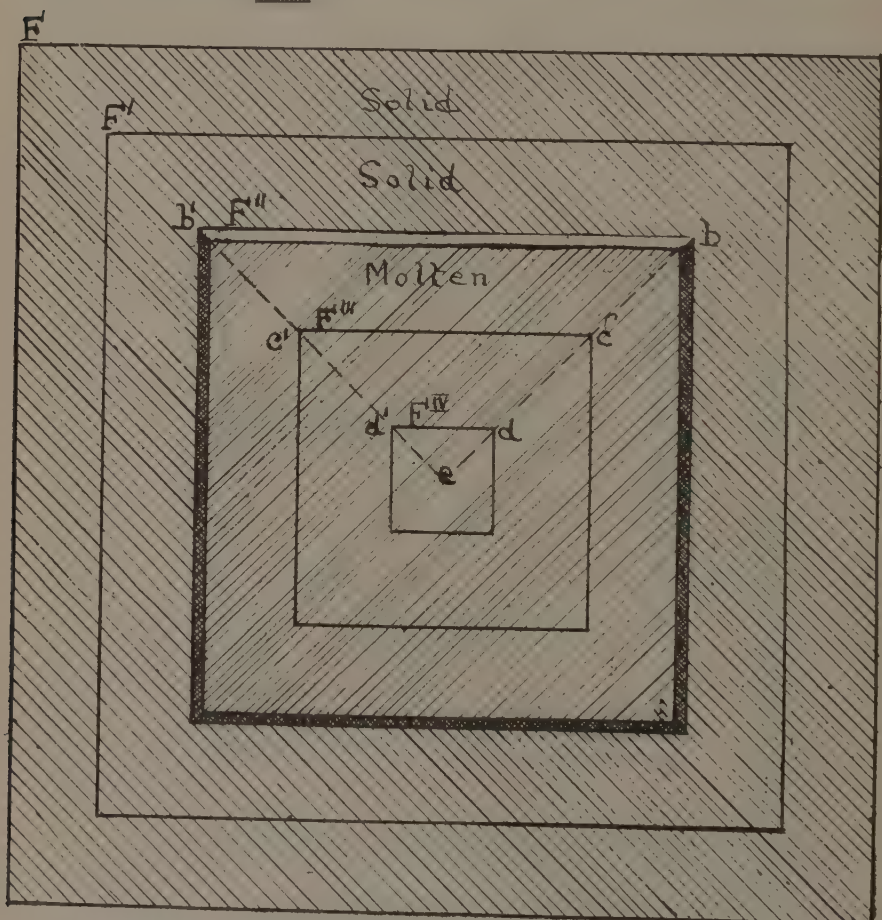
But the excess of contraction of the interior of the ingot over that of the shell from the neutral moment on gives rise to a void which at every instant is equal to that excess. Where will this void lie?

The Top of the Pipe Represents the Top of the Molten at the Neutral Moment.

If Fig. 1 represents a cube of molten steel in an iron mould losing heat equally in every direction, then the concentric squares F, F^{I}, F^{II}, etc., are *isotherms.* One

FIG. 1. VERTICAL SECTION THROUGH A SOLIDIFYING STEEL CUBE.

Metal Solidified in the Pre-neutral Period
Metal Solidified Between the Neutral Moment and the Period Represented by the Sketch
Metal Still Molten



NOTE TO FIG. 1.—The top of the pipe b^1b corresponds to the upper surface of the molten at the neutral moment. With uniform heat escape, and under certain ideal conditions, the bottom of the pipe should be at the centre of gravity, but for sagging.

specific isotherm concerns us greatly, that of the freezing point, assuming for simplicity that the metal has a definite freezing point instead of a freezing range. This we may call the *tectotherm.* During the pre-neutral period the tectotherm coincides at every instant with the top, bottom, and sides of the cave, which are also those of the molten.

Let cube F^{II} of Fig. 1 represent the tectotherm and hence the outline of the cave at the neutral moment. Clearly the deficit of contraction of the interior compared with the exterior, a deficit which begins with the post-neutral period, or in other words the shortage of the molten compared with the volume of the cave, will henceforth prevent the top of the molten from reaching quite to the top of the cave, with the result that, a few moments later, a thin flat void will exist, such as is shown just below the top of cube F^{II}. This void, which is the beginning of the pipe, will persist.* In order to show it I have to give it a visible thickness, such as it will reach shortly after the post-neutral period begins. But its very incipiency occurs at the neutral moment, and by parity of reasoning, its incipient width, that is its width at its very top, is that of the top of the tectotherm at the neutral moment, which is also that of the molten then, Q. E. D.†

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*The slight narrowing, due to the linear contraction of the solid metal from the freezing point down, need not here be considered.

† That the inner part of the walls should be contracting more rapidly than the outer part at the relatively early stage in the solidification at which the pipe begins forming may surprise us. Perhaps an easier way of understanding this is to conceive the thermal gradient as extremely steep at the beginning of solidification, and as nearly flat when cooling is nearly complete, and thence to infer that its steepness decreases continuously from the beginning, or at least from very early in the solidification to the end of cooling. But a flattening of the thermal gradient means that the outer parts are cooling more slowly than the inner.

A more accurate but more complex picture is that, because they are integrally united, the various concentric layers which make up the already solid walls, are striving against each other because of their different rates of cooling. This struggle will go on with varying resultants, but with the general result that the progressively firmer outer parts resist to ever better advantage the tendency of the faster cooling inner parts to drag them inwards. This result in time brings on the neutral moment when the actual inward travel of the inner face of the walls ceases to exceed the shrinkage of the molten caused by the continuous transfer of its particles to those solid walls.

The special properties of iron, such as its marked expansion in cooling through the transformation range, offer themselves as tempting explanations of why the pipe forms, that is why the volume of the cave begins at the neutral moment to exceed that of the molten, thus giving rise to the void or pipe. But this temptation is to be resisted, not so much because this expansion is a wave which passes through from crust to centre, and hence explains that exceeding only lamely, as because the pipe forms in the solidification of so many different kinds of substances, which undergo no corresponding transformation after solidification.

The Width of the Pipe at Every Level Is the Width of the Top of the Molten When at That Level.

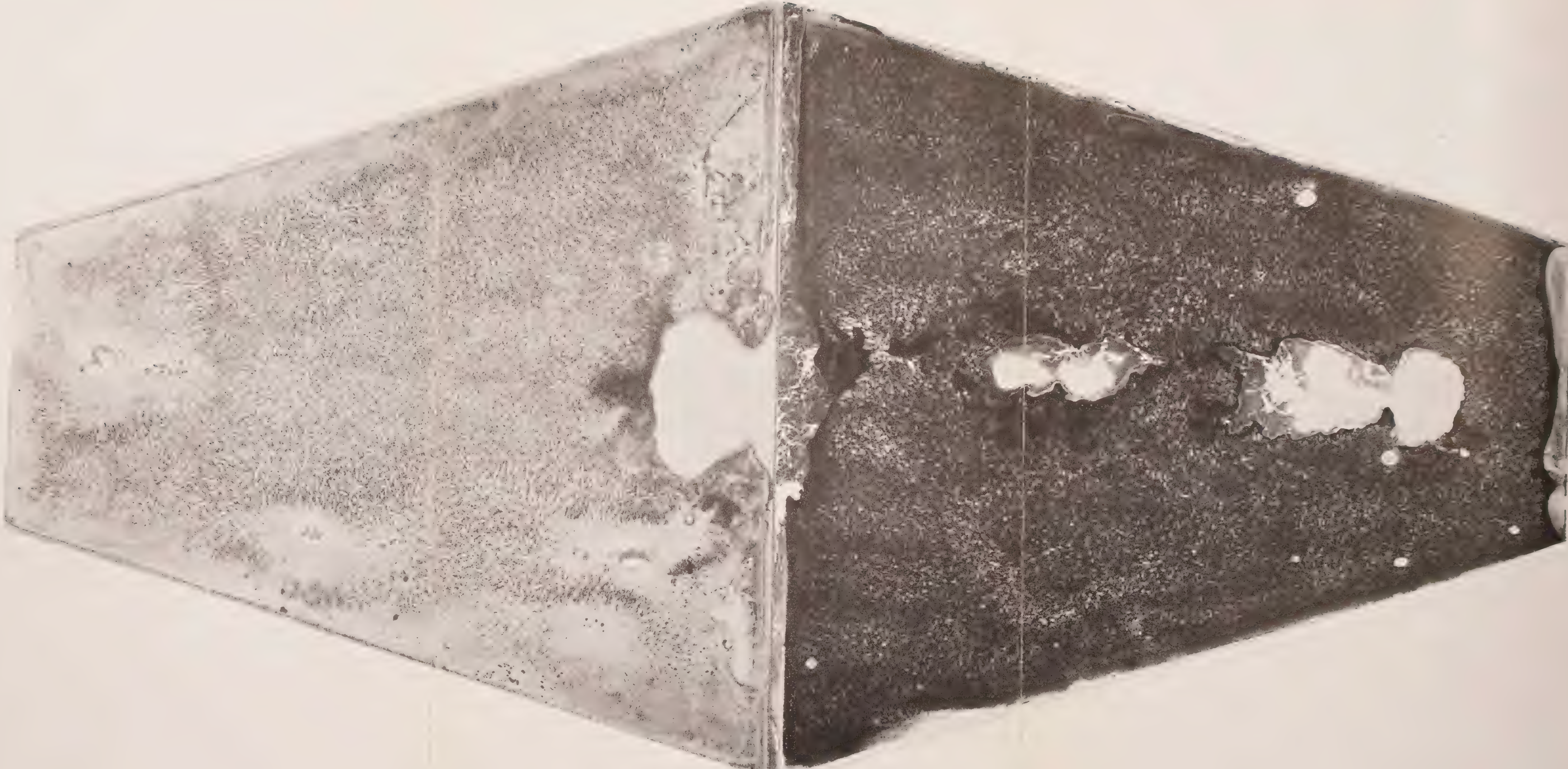
At this moment the width of the top and of the bottom of the void are practically the same. As freezing proceeds, the continuing deficit of contraction of the interior compared with the exterior leads to a continuous increase in the volume of the void. Its top will remain that with which it started, and its bottom will be the surface of the molten at each successive instant. To trace the position of this bottom accurately would carry us too far, but to fix our ideas we may imagine that the increase of volume of the void just keeps pace with the thickening of the walls, so that when, in the course of solidification, the walls and bottom of the cave have become those of cube F^{III}, the top of the molten will have sunk so as to coincide with the top of F^{III}, and that the same holds true of cube F^{IV}. The width of the pipe at each level will be the width of the cave at that level at the moment when the surface of the molten is at that level, and hence under our present assumptions, will at stages F^{III} and F^{IV} coincide with the width of cubes F^{III} and F^{IV}. Hence after solidification is complete, the outline of the pipe will be represented by the lines bcde, $b^Ic^Id^Ie$, an inverted cone with its apex at the centre of gravity of the whole, and its base where the top of the tectotherm was at the neutral moment.

To Raise the Isotherms Raises the Pipe.

Though the foregoing assumptions are not accurate, they suffice to show us that the position of the pipe depends on the successive positions of the isotherms, of which the tectotherm is but one. Hence the inference that to raise the isotherms raises the pipe. In particular to raise the position which the tectotherm occupies at the end of solidification is to raise the bottom of the pipe, and thus to reduce the discard needed for removing the pipe. But to raise the isotherms is only a philosophical way of saying that *the cooling of the top should be made to lag as*

A Fig. 2. B

THE PIPE STRETCHES APPROXIMATELY FROM THE LEVEL OF THE TOP OF THE CAVE AT THE NEUTRAL MOMENT TO THAT OF THE BOTTOM OF THE CAVE AT THE END OF SOLIDIFICATION, AS SHOWN BY AN ETCHED LONGITUDINAL SECTION OF TWO CASTINGS CAST AS SKETCHED IN FIG. 5. APPROXIMATELY ACTUAL SIZE.



A

B

Fig. 3.

THE SEGREGATE LIES NEAR THE BOTTOM OF THE PIPE. SULPHUR PRINT OF THE CASTINGS SHOWN IN FIG. 2.

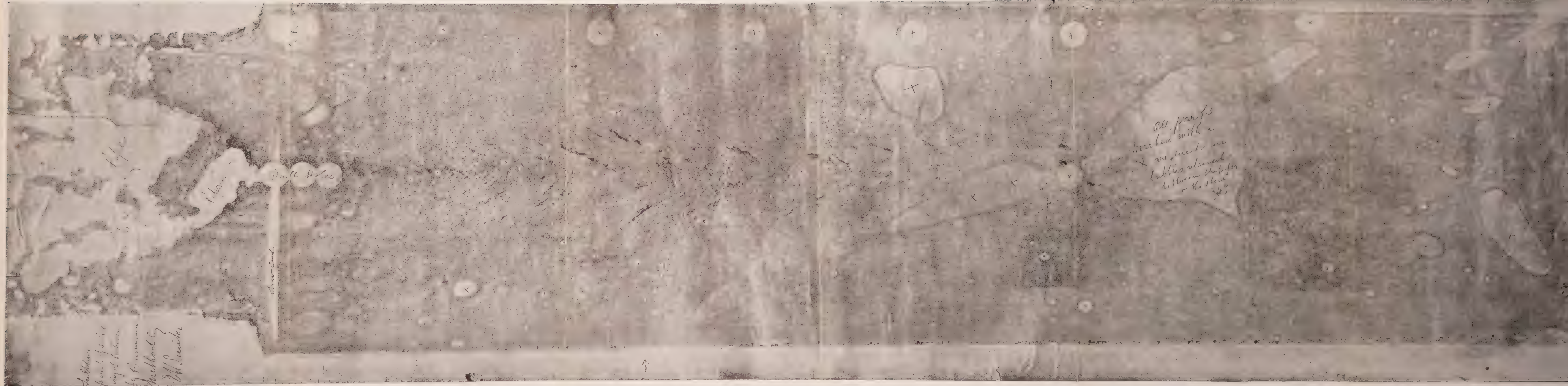


Fig. 6.—CASTING C, SHOWN FULL SIZE

tions are not so unfavorable to narrow-top castings in actual practice, because here the narrow-topped ingot does not in addition have its apex chilled by the contact of the mould and its base warmed by that of a body of hot metal below. But for gravity and for the exposure of the top to warm air instead of to the cold stool, the pipe might be expected to be as much below the centre of gravity in a narrow-topped ingot as it is above that of a wide-topped ingot. But in lifting the pipe, gravity moves it exclusively up and away from the centre of gravity of a wide-topped ingot, whereas in a narrow-topped one part of this lifting effect of gravity is consumed in bringing the pipe from below up to the centre of gravity, and only the residue is available for lifting the pipe above that centre.

The massing of metal at the top of a wide-topped ingot clearly favors sagging and the resultant raising of the pipe.

Top Heating, which in effect raises the isotherms by retarding the cooling there, may be brought about by means of a coke, gas, or other fire, by electric heating, or by pouring on molten slag. Hadfield's process for preventing the heating agent from carburizing the upper part of the steel by interposing a slag buffer is important. Remarkable results are rumored to have been reached by covering the top of the molten metal with graphite, which should carburize the metal there, lower its freezing point, and thus prolong the period during which it remains fluid enough to sag and feed the pipe.

Top Insulation, which raises the isotherms by retarding the escape of heat from the top, may be effected by the use of clay or other non-conducting prolongations of the mould, which may be preheated as in crucible practice, thus adding top heating to top insulation, or by coke, clay, or other coverings, cold or hot. Indeed most of these steps do both. Gathmann's moulds, thicker below than above, in a sense cause top insulation, in that they

remove heat less rapidly from the top than from the bottom.

Open Top. The usual practice of either covering the upper surface of the ingot with sand or other insulating material or leaving it open to the air, is in effect a form of top insulation, for the escape of heat is less rapid into the sand or air than into the cold iron mould walls.

Top Replenishment, by adding molten steel towards or after finishing the pouring of the ingot proper, both helps directly to fill the pipe, and also gives top heating.

Slow Pouring is a very cheap and effective mode of replenishment. Clearly, retarding the pouring raises the isotherms by heating the top while the lower part is losing heat rapidly into the mould walls. Slow pouring is thus in effect a kind of top heating. I have found that by pouring very slowly from a heated ladle I could efface the pipe completely under conditions which otherwise led to a very deep pipe.

Bottom Pouring, for like reasons, tends to deepen the pipe, by adding fresh hot metal to the bottom of the ingot even after most of it has been poured and has started to transmit its heat into the mould walls. It thus lowers the isotherms and with them the pipe.

Sink Heads act through top replenishment, top heating, and in a sense through slow pouring. They feed down as fast and only as fast as the pipe tends to form.

Pipe Filling Chiefly from Below.

The slower contraction of the outer than of the inner parts of the solid walls during the post-neutral period may be prevented or cured forcibly by mechanical compression after many different methods, by compressing the ingot lengthwise in Whitworth's way, with perhaps the maximum pressure requirement; or by driving the ingot as a tapered plug into a tapered hole as in Harmet's way; or by pressing in one of its flat sides in S. T. Williams' way, with perhaps the minimum of pressure; and

in any one of a dozen other conceivable methods. Except in the case of very large ingots mechanical compression often seems like doing by brute force what could be done by finesse, by planning the thermal conditions. Compression generally has to be postponed till after the solidification has progressed far, when it has to overcome very great resistance from the already solid walls of the ingot. great resistance from the already solid walls of the ingot.

PIPE FILLING BY MEANS OF BLOWHOLES.

The commonest method of all is to limit carefully the killing of the molten steel so that it will evolve gas rather late during solidification, and therefore cause blowholes which are deep enough not to oxidize. In effect these puff up the inner parts of the already solid walls, and thus cancel their tendency to cause a pipe by contracting more slowly than the outer parts. This effect can be traced in Fig. 4, in which the abundance of the blowholes has reduced the pipe, P, to its relatively small size. Not only the white vermicular spaces at the right but also most of the light gray ones there are blowholes, whereas the darker gray ones on the left are segregates, apparently blowholes into which segregate has been squeezed after their formation. The volume of the blowholes cannot be regulated closely, and hence it is usually restricted so that it is too small to close the pipe completely. In this case it is an incomplete remedy of one defect at the cost of introducing two others, the blowholes themselves and the segregation which they induce, as explained below. Moreover, blowholes are spaces into which minute pocketfuls of local segregates can be squeezed, by the pressure generated spontaneously within the ingot, thus forming masses so large that their diffusion is far less complete than it would have been had they remained in their initial inter-dendritic positions. In the case of basic open-hearth boiler-plate ingots these defects are relatively harmless, because the blowholes weld readily in this low-carbon metal, and because it is so pure that

its segregation is not serious, the segregate being buried away in the middle of the plate, both at the neutral axis and away from corrosion.

In general to prevent piping by creating blowholes seems the least intelligent though often much the cheapest method. In the case of the higher carbon steels and the alloy steels it is hardly to be considered, because here the blowholes will not weld. We may question whether it is consistent with proper regard for the lives of travelers to tolerate this practice in making rail ingots.

Of the various deoxidizing additions for preventing blowholes, by removing the oxygen which otherwise would combine with the carbon present to form carbonic oxide gas, that would seem the best which, while deoxidizing the metal thoroughly, yields a fusible or rather a coalescing slag which will swim to the surface and escape. The composition of the resultant slag must needs vary, for any one kind of addition, with the quantity of oxide to be removed, which in turn must vary from heat to heat. Direct experiments are needed urgently to show what combination of these additions will, under the probable range of oxygen content of the metal, yield the most thoroughly self-expelling slag. The thoroughness with which blowholes, and their result, segregation, have been suppressed in this or that heat by one or another deoxidizer is weak evidence. I have heard of no attempt to make the needed experiments intelligently.

The Rate of Solidification.

The formation of the pipe being due to a difference between the various layers as regards their rates of contraction, none could form if there were no such difference, and its volume and depth must clearly decrease as this difference decreases, being for instance much less when a wide ingot solidifies in a soaking-pit than when a narrow one solidifies in a strong winter's wind. Rapid solidification increases the formation of blowholes, as is shown by the great excess of those in the right hand or

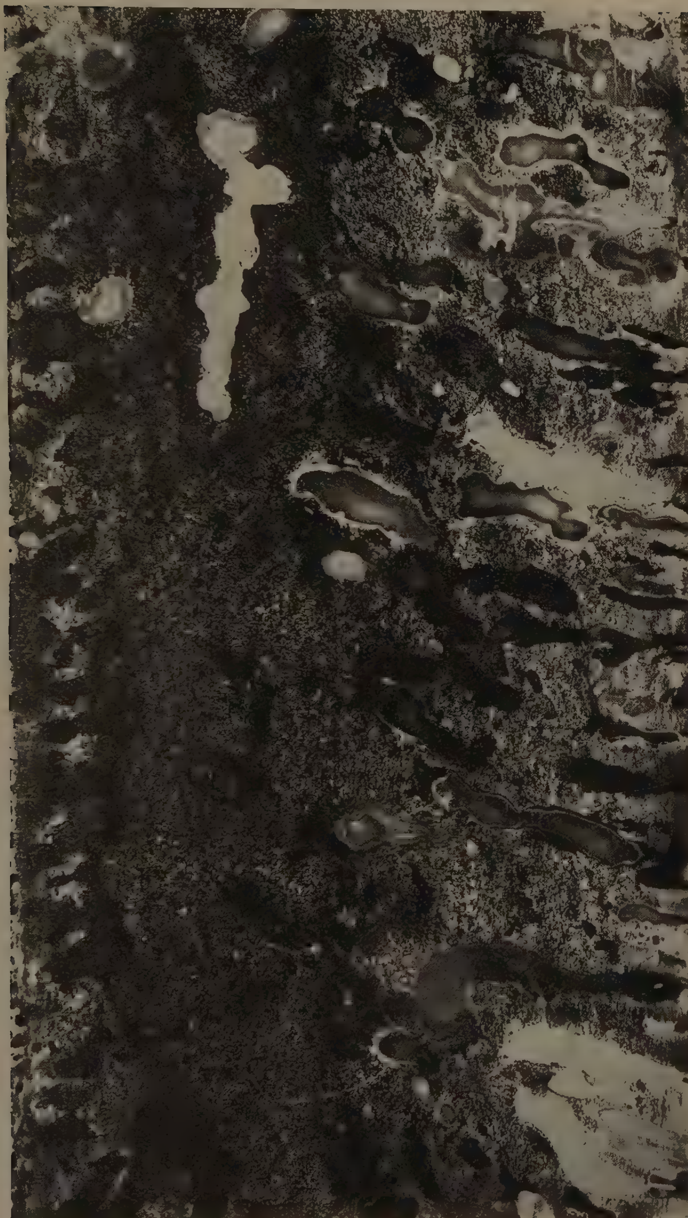


Fig. 4.

The pipe is lessened by blowholes, and with the segregate lies on the slower-cooling side of the casting. Rapid cooling exaggerates the blowholes.

Sulphur print of a casting of wild steel, with its left side cast against sand, its right against a chill.

chilled side over those on the left hand or slowly cooled side of casting C, Fig. 4.

Segregation.

Solidification is a process of differentiation. The carbon content of the particles of solid metal which first deposit on the sides of the mould is only a certain fixed* percentage of that of the molten out of which they deposit. So with the phosphorus and sulphur. They may here be left out of account, because what is true of carbon is true of them. Because this process enriches the molten progressively, and because the carbon content of the solid particles deposited at any instant is proportional to that of the molten out of which they deposit, the carbon content of the successive solid layers as they deposit increases progressively from beginning to end of the solidification. Hence the successive positions of the tectotherm are recorded permanently by successive lines of nearly equal carbon content, or isocarbs, the carbon content being smallest at the outer crust and greatest at the last solidifying point.

The Onion and Landlocking Types of Solidification.

The condition just described assumes that the successive layers which deposit are smooth and concentric, or at least co-axial with the mould, like the layers of an onion. But instead landlocking solidification may occur by the inshooting of pine-tree growths from the sides. The interlacing boughs of these pine-trees landlock the metal, so that the progressive enrichment, instead of being from the outer crust of the ingot as a whole to its axial last freezing point, is from surface to centre of each one of these little pockets.

Even in this case there is some concentration of carbon from the outer to the last freezing parts of the ingot as a whole, but the concentration is much less than in the

* Fixed for given carbon content of the molten. As this content varies, the ratio which it bears to the carbon content of the depositing layers varies slightly, but not to a degree that concerns us here.

onion type, a large part of the carbon which in the onion type is crowded progressively to the last freezing axial point being locked up locally in these little pockets.

We may surmise that the columnar outer part of the ingot has solidified pine-treewise, and the granular inner part onionwise. When the pine-tree type is replaced thus at the end of the columnar region by the onion type, the type of segregation changes with it from being local, little pools of molten concentrating their carbon into their own little centres, to being general, the mass as a whole henceforth concentrating its carbon towards its last freezing part in the axis of the ingot. This implies a sudden increase in the thoroughness with which the carbon is moved towards the last freezing part of the ingot as a whole and away from these layers now solidifying. Hence arises what is often called *negative segregation,* which means only that the impoverishment of these relatively early freezing layers is no longer interfered with by local retention of the carbon in little pine-tree pockets, so that as we pass horizontally in the lower part of the ingot from the columnar region into the granular part, the carbon content decreases, and sometimes very considerably.

The landlocking type of solidification and segregation should yield greater homogeneousness, first because it lessens the axial enrichment, and second because its local variations in carbon cover such small distances that they are readily effaced, or at least greatly lessened, by diffusion aided by the kneading of rolling and forging.

Lessening Segregation.

The most effective means is quiet, probably because this leads to undercooling and hence to the pine-tree landlocking type of solidification, as explained in the discussion of Mr. Kenney's paper* at our last meeting. The boiling caused by the rise of part of the gas of which the remainder causes blowholes is the greatest disturber

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* Edward F. Kenney, *The Commercial Production of Sound and Homogeneous Steel,* Proceedings of the American Iron and Steel Institute, May, 1915.

of quiet, and hence wildness is the greatest aggravator of segregation. In most cases the rational procedure is to quiet the steel completely so as to prevent blowholes, and thereby to lessen segregation, and in addition to prevent, in the ways sketched above, the pipe which the absence of blowholes tends to cause. The effect of quiet is illustrated by a comparison of the quiet steel of Fig. 3 with the wild steel of Fig. 4. Though each of the pyramids of Fig. 3 is about thrice as large as the prism of Fig. 4, the volume of the segregate in the latter seems larger than in the former. An examination of casting A of Fig. 3 shows its fine colonial dendritic structure, with little local segregates landlocked between the trunks and branches.

Probable additional means of making the solidification landlocking, and thereby lessening segregation, are to induce rapid solidification by means of a casting temperature so low that the mould walls store up but little heat before the metal begins solidifying; casting in massive cold moulds which remove the heat rapidly; casting in narrow ingots which cool rapidly; and early stripping. Of course to hasten solidification is to deepen the pipe.

Position of the Segregate.

We have seen that at every stage during solidification the existing bottom of the void or pipe is the existing upper surface of the molten.

This is true also of the last stage of solidification, when the molten is reduced to its last drop. With the freezing of that last drop the bottom of the pipe becomes the bottom of that drop. Because that drop is the final product of the continuous process of enrichment, it is the richest spot of all. Hence the richest spot lies at the bottom of the pipe, for instance just below that of casting A of Fig. 3. The segregate can be seen massed below both the pipes of casting B of Fig. 3.

This inference is supported by the eccentricity of the segregate in casting C, its following the pipe to the slower cooling side of the ingot.

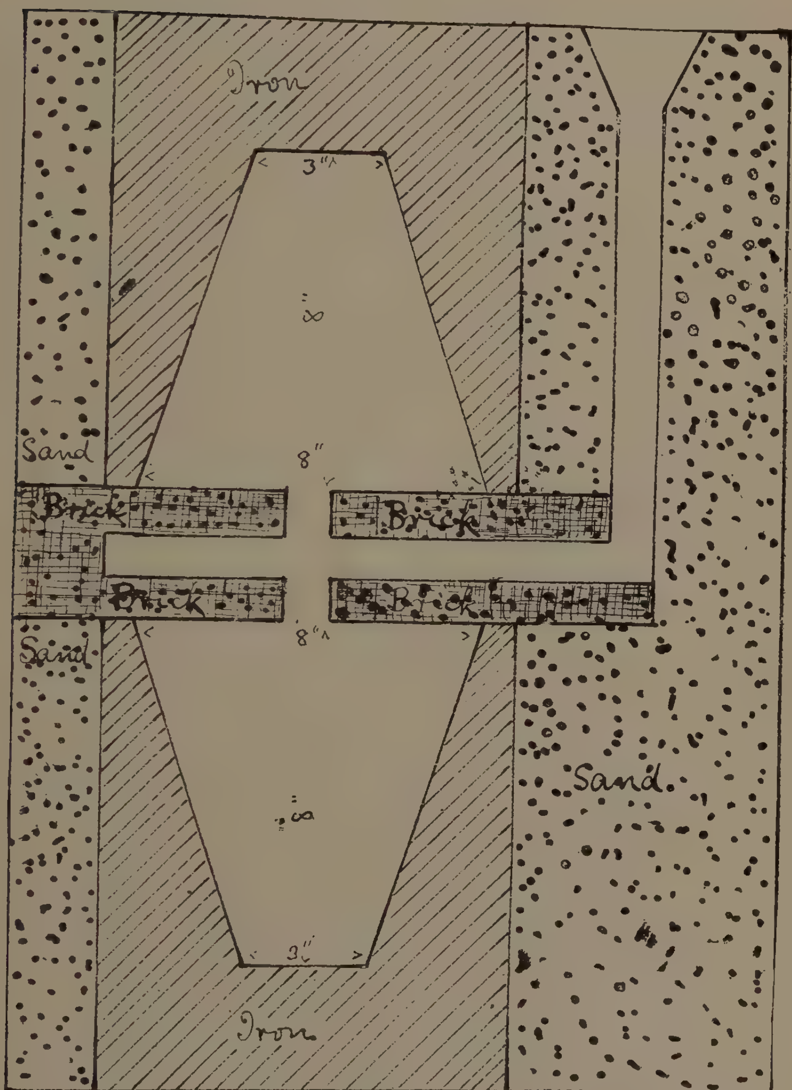

Fig. 5.

Vertical section through the mould for the steel casting shown in Figs. 2 and 3.

The position of the segregate with regard to the pipe bottom may be modified by various minor conditions. After solidification is complete the sides of the pipe may sag down enough to cover the richest spot with a considerable layer, especially if the cooling is very slow and the opportunity for sagging is therefore long. Or that drawing apart of the inner parts of the ingot which caused the pipe during solidification may continue after solidification, and thus split apart the solid metal below where the bottom of the pipe lay at the end of solidification, and so prolong the pipe below the richest spot, which will then be found on the walls of the pipe, and thus higher up than its bottom.

Because the position of the segregate is affected less than that of the bottom of the pipe by the swimming of the void and by sagging and tearing after the end of solidification, it follows the isotherms even more docilely than the pipe does. Thus in casting B of Fig. 3, while there is indeed segregate just below both the pipe bodies, yet there are other masses of it even lower down than the bottom of the lower pipe. Part of the segregate indeed forms a layer stretching across most of the lower edge of this casting. We may surmise that this was the very last part of this casting to solidify, and that the higher position of the pipe than of the segregate is due to its swimming upwards through the viscous metal.

The high position of the segregate is often thought to be due to the lightness of the segregating elements, carbon, phosphorus, and sulphur. But its position is governed primarily by the contours of the isotherms, as is shown by its being near the bottom of casting B but near the top of A, just below the pipe bottom in each, though these were cast simultaneously from the same ladleful. This is shown also by its being at the right-hand side instead of at the axis of casting C.

Littoral Convection.

But lightness probably contributes. The splitting-up

of the layer in the act of solidifying into a fraction poorer in carbon which solidifies and one richer in carbon which remains molten, makes the layer of the molten along the walls of the cave richer in carbon than the average of the molten, and because richer lighter. Hence arises an upward convection current of the local layer thus enriched, along the walls of the cave, leading to a certain degree of stratification, the lighter and richer parts yielding readily to this upward convection, but offering a moderate resistance to any corresponding downward convection.

Any evolution of gas in the molten metal occurs at these same walls, and the rise of this gas in small amounts helps this upward convection. It may be for this reason that the upward concentration of the segregate is so marked in the casting of Fig. 4, which formed many blowholes, whereas those of Figs. 2 and 3 formed none.

Littoral convection increases upper-axial segregation in an additional way. Because the carbon content of the solid particles which deposit on the sides of the cave increases with that of the molten out of which they deposit, this lifting of the enriched shore-layers of the molten, in that it correspondingly lessens the carbon content of the molten out of which the next succeeding solid particles will deposit on the lower part of the walls of the cave, lessens their carbon content, too, while enriching correspondingly those next to deposit on the upper part of those walls. (Applause.)

President Gary: Discussion by Mr. E. F. Kenney, of the Cambria Steel Company.

GENERAL PRINCIPLES OF THE CONTROL OF PIPING AND SEGREGATION OF STEEL INGOTS

DISCUSSION BY EDWARD F. KENNEY
Metallurgical Engineer, Cambria Steel Company, Johnstown, Pa.

Dr. Howe has given us an explanation of many of the features which we have observed in the cooling of ingots, and in the main this reasoning is corroborated by our observations. His analysis of the influence affecting the relation of the solid and molten portions of a cooling ingot is most interesting, but his statement that during the whole of the preneutral period (*i. e.*, the period during which the outer parts cool faster than the inner), the contraction of the outer parts tends to be more rapid than that of the central ones, is not necessarily true. It would depend on the relative coefficients of contraction of the two parts. The outside walls might be cooling much faster than the molten interior, but if the coefficient of contraction of the molten metal were sufficiently great, its shrinkage might be much greater than the contraction of what Dr. Howe has called the cave. That this is what actually occurs is indicated by observations on sink-head ingots of thoroughly deoxidized steel, which have been kept open on the top. Instead of the molten metal rising in the sinkhead, as would be produced if the contracting walls reduced the volume of the cave faster than the volume of the contained metal was reduced by shrinkage, there is a continuous lowering of the level of the molten metal.

This seems to be characteristic of all ingots cast from killed steel. In these the pipe cavity extends practically up to the top of the ingot, indicating that the shrinkage of the molten metal is greater than that of the cavity containing it practically from the time of

casting. In ingots cast from steel which is not thoroughly deoxidized, and in which consequently there is an evolution of gas, forming blow holes, we have observed a condition similar to that described by Dr. Howe, and a considerable zone of solid steel is found between the top of the ingot and the top of the pipe cavity. In these cases, however, the metal continues to fill the cavity, not because the cavity is being reduced by a shrinkage of the walls, but because the volume of the molten metal is being increased by the formation of blow holes within it.

There is just one other point on which I am not convinced by Dr. Howe's reasoning. This concerns the effect on segregation of the upward currents caused by the gas bubbles in a rising steel.

In my judgment this is a very important factor in the intensifying and localizing of segregation. When lively steel is poured into an ingot mold, there is a very rapid evolution of gas which causes an intense boiling in the mold. There can be little doubt that this violent boiling does keep the metal thoroughly mixed, but as the steel cools, the amount of gas evolved gets very much less. A few bubbles rise in the steel, generally along the edge of the freezing metal, bringing up with them metal which is so near its temperature of solidification, that it can be seen to freeze almost immediately after being ejected from the little craters which are kept open in the top of the ingot by the escaping gas. It is at this stage that the segregated metal is brought to the top of the ingot, and there is not sufficient downward current to overcome the tendency of the lighter, more segregated metal to remain at the top after being brought up. The marked segregation found in the zone of the deep-seated blow holes when they are present in considerable numbers, is strongly corroborative of this theory. (Applause.)

GENERAL PRINCIPLES OF THE CONTROL OF PIPING AND SEGREGATION IN STEEL INGOTS

Comment of Professor Howe, Filed After Meeting

The last paragraph but one of my paper shows that I am in general agreement with Mr. Kenney as to the raising effect of a gentle evolution of gas on the segregate, but his words indicate that he refers a greater fraction of the total raising influence to this gas than I do. The enrichment of the zone of the deep-seated blowholes does not seem to me to bear directly on this question if, as indicated in the section headed "Pipe Filling by Means of Blowholes," this local enrichment represents the filling of certain blowholes with molten squeezed from between the neighboring pine-tree trunks by pressure arising after the blowholes have formed.

It seems to me difficult to determine what fraction of the elevating action is due to rising gas, and what to the other causes, to the contour of the isotherms, and to the littoral convection due to the enrichment in carbon, and consequent lightness of the littoral metal, by the differentiation which occurs in solidification. It is difficult to determine this fraction, because the formation of blowholes increases the segregation in a wholly distinct way, by preventing undercooling and in general changing the type of solidification.

Mr. Kenney's other point is perfectly well taken. It is not the rates of cooling of the various parts, but the relation between their rates of contraction, that determines the arrival at the neutral moment. This relation, while governed in large part by the ratio of the rates of cooling of the various parts, is governed also in part by the ratio of the coefficients of contraction of those parts. If the coefficient of the molten is far greater than that of the solid, that would help to explain the surprisingly early stage of the neutral moment. The bridge which covers the pipe in crucible steel ingots is often so thin as to reinforce the cases which Mr. Kenney cites as showing the earliness of the neutral moment.

One hesitates to attribute a great influence to a difference between molten and solid as regards their coefficient of contraction, first, because this influence must be as the product of this difference into the range of temperature through which the molten cools during its solidification after the outer crust of the walls has formed, and second, because this surprising earliness of the neutral moment occurs also in cases in which the metal when cast is only very slightly above its freezing point, or more accurately its liquidus. With this range as the multiplicand one hesitates to ascribe to the difference in coefficient of contraction as multiplier a value great enough to yield an important product.

Nor do we find an easy escape from the difficulty by supposing that the metal contracts greatly in passing from the molten to the solid state, in view of the persistency with which cold masses charged into nearly deadmelted open hearth steel swim on the surface. Here the evolution of gas, which might explain the floatation on oxygenated molten metal, hardly suffices. The difficulty is increased by the fact that such a pipe forms, and, as far as my observation goes, in such a position as to point to a surprisingly early neutral moment, not only in steel but in other metals and in many other substances.

Mr. Kenney points out privately that many present careful specifications conform with the common and reasonable belief that bottom pouring tends to lower the pipe and the segregate, for the reasons which I give, by calling for a much larger top discard from bottom than from top-cast steel. This disadvantage of bottom pouring may often be outweighed by its advantage of giving a smoother skin, by avoiding the spattering incident to top pouring.

President Gary: If there is no further discussion, the next subject to be presented is "The Mechanical Development of Sintering of Iron Bearing Materials," by Bethune G. Klugh, Chemical and Metallurgical Engineer, American Ore Reclamation Company, New York City.

THE MECHANICAL DEVELOPMENT OF SINTERING IRON BEARING MATERIALS

BETHUNE G. KLUGH

Field Manager, American Ore Reclamation Company, Pittsburgh, Pa.

In considering the problem of sintering, it was early demonstrated that certain essential features of operation must be determined and maintained constantly under control, in order to produce maximum quality and quantity of sintered product.

The requirements include:

(1). Maintenance of accurate and uniform proportioning of the various materials which make up the sintering mixture;

(2). Maintenance of homogeneous mixing of these materials;

(3). Accurate proportioning and mixing of the water required to be added for producing the ideal moisture content for a sintering mixture;

(4). Delivery of the sintering mixture to the sintering device so as to permit the most permeable and homogeneous bed over the entire hearth area, and a readily adjustable depth of charge to that which proves most efficient for the specific material treated;

(5). Ignition of the surface of the sintering charge with proper and uniform intensity over the entire surface;

(6). Exhausting the waste gases so as to conduct through the interstices of the charge the largest volume of air that can be usefully applied, but so as to avoid an excessive pressure which would compact the charge and thus reduce its permeability.

The purpose of this paper is to describe the mechanical improvements that have contributed to the progress

made in sintering iron bearing materials by the Dwight and Lloyd continuous process.

The above mentioned features are those which apply to the sintering operation itself, and each one is attained through mechanical means. In addition to these operations, it is obviously essential that all the work of handling material and product to and from the plant be done efficiently and economically, in order that the operation be commercial.

Types of Sintering Plants.

Two types of general arrangement of sintering plants have been developed:

(1). That with storage bins placed on the ground, in which the proportioning of the sintering mixture is effected, and the mixture then elevated.

(2). That with storage bins elevated so that only one elevating operation is required, and all handling after proportioning is accomplished by gravity.

While all elevating and conveying machinery is an item of expense as to maintenance, a certain amount is necessary in order that all the functions be most efficiently performed. Bucket elevators, inclined belt conveyors, grab buckets and skip hoists are all applicable to sintering plant operation, depending upon local plant standards and conditions. The types adopted should, of course, be selected by considerations in order named:

(1). Efficient operation;

(2). Low maintenance and operating costs;

(3). Low installation cost.

The materials treated include flue dust, magnetic concentrates, pyrites cinders, high sulphur magnetites, hematites, also plastic and hydrated ores. Regardless of what material it is purposed to treat at any particular works, it is not probable that this material will be treated exclusively throughout the life of the sintering plant. Therefore, it is necessary that the handling equipment in-

stalled be applicable to as wide a range of materials as it is possible to make it.

One plant that was installed for the exclusive treatment of flue dust has in three years of its existence sintered and desulphurized, on a commercial scale, flue dust, magnetic concentrates, pyrites cinders and hydrated hematite ores.

Screening the Materials.

At the present time flue dust is the material which has the greatest sintering interest. Flue dust should be screened prior to sintering. The larger sizes of coke, that is, sizes larger than one-half inch, have no value as a sintering fuel, but have a value for other purposes when screened free from flue dust. All of the various types of screens on the market have been used for screening flue dust. The usual types of revolving and reciprocating screens have been somewhat disappointing. Perfectly dry flue dust as taken from the dust catcher can be effectively separated on almost any type of screen. However, it is essential to provide for the screening of stockpile flue dust, which is delivered to the sintering plant in a moist condition, usually with five to eighteen per cent. moisture.

The American Ore Reclamation Company has developed a screen upon a somewhat novel principle, which screens flue dust of the above character and delivers oversize coke sufficiently clean for use as a blast furnace fuel, and other purposes, according to size.

The special characteristics of the screen are its self-feeding and self-cleaning features. A modification of this screen has been installed at the Central Furnaces plant of the American Steel and Wire Company. Its arrangement, which was developed by the mechanical department of these works, is very ingenious, in that the flue dust is delivered to the screen directly as taken from the stockpile by the grab bucket. The advantages of this particular arrangement are purely local, and in a new plant

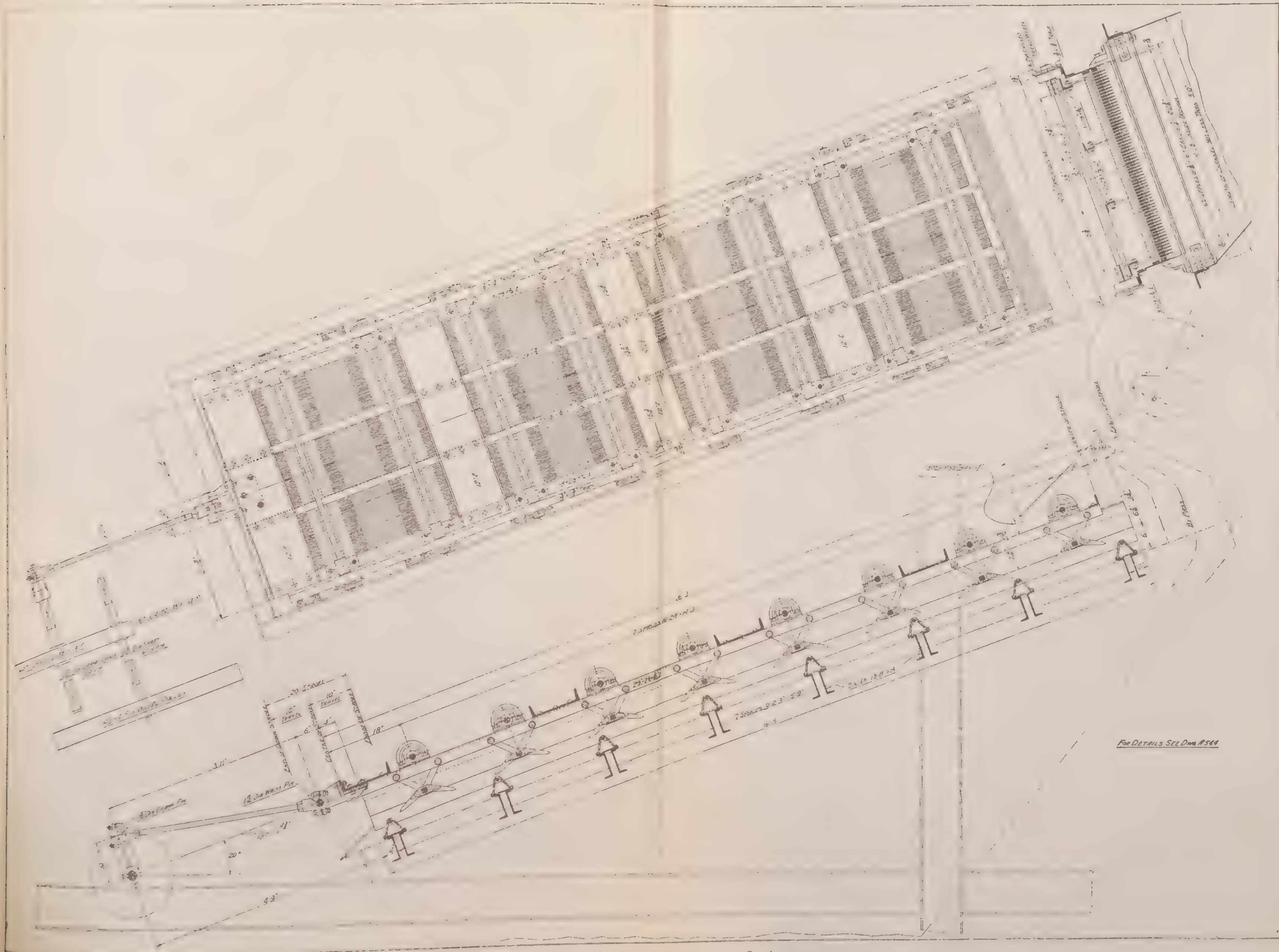

FIG. 1.—Reciprocating self-cleaning flue-dust screen.

such a screen should be an integral part of the sintering plant, and should handle all materials.

Figure 1 shows the reciprocating type. Figure 2 is a cut showing the Central Furnaces screen equipment. The principle of both is the same. In the type shown in Figure 1, cleaning fingers are reciprocated between sta-

Fig. 2.—Stock-pile flue-dust screening plant at Central Furnaces, Cleveland.

tionary screen bars. The Central Furnaces type reciprocates the bars between the stationary fingers. Its performance is very satisfactory.

This type of screen is recommended for flue dust, but it is applicable to other materials requiring sintering. However, magnetic concentrates and pyrites cinders usually have been subjected to sufficient screening action in their production. The arrangement of each sintering plant should utilize local conditions to best advantage, but almost universally the material to be sintered should be screened prior to placing in the sintering plant bins.

The screen may operate integrally with the bin-loading equipment with advantageous operating costs, but such arrangement is not essential. The proportioning of the various materials which enter the sintering mixture must be accurate in order that such proportioning be of any value. If an indeterminate quantity of oversize is screened out of any constituent after the proportioning is done, accuracy is impossible.

Flue dust, as all experience shows, is about the most difficult material to handle. Its angle of repose has been said to be 0 degrees when dry and 90 degrees when wet. It was after considerable experience, under widely varying conditions, that the screen above described was developed.

It is, of course, desirable to take current make of flue dust direct from dust catchers to the sintering plant and thus eliminate the expense of unloading and eventually reloading at the stockpile. The great disadvantage in such procedure lies in the dust nuisance involved. It is practically impossible to handle dry flue dust in any plant without filling the atmosphere of the plant with dust, with its incident detriment to all operators and to the machinery. It is practically impossible to effectively moisten hot and dry flue dust by the usual means of a hose. A puddle of water may be placed on top of a car of hot flue dust and the material remain hot a foot below. The dumping together of wet and of hot flue dust has

often caused disastrous effects due to precipitating hot dust upon workmen.

The problem has been very satisfactorily solved by the following procedure: The car of dry dust is dumped into a receiving hopper; the dust thrown into the atmosphere from this dumping operation is considerable, but it is only momentary and is outside the plant. The material is then delivered to a screen and passed from the screen directly into a short pug mill and moistened. The feeders from the receiving hopper as well as the screen and pug mill are wholly enclosed so that no dust is thrown into the surrounding atmosphere. The material leaving the short pug mill contains just sufficient moisture to prevent any dust being thrown into the atmosphere, and yet giving it a free flow angle. The description of this detail may appear of a kindergarten nature, but the small operation described has satisfactorily solved the dust problem in some sintering plants.

Proportioning the Materials.

In order that two or more finely divided solid materials be accurately and continuously proportioned, a feeding device of simple, accurate and dependable characteristics should be provided. After trying a number of types and various modifications of these types, a modified form of the revolving disc feeder has proven satisfactory. The form finally adopted is shown in Figure 3. This feeder has the following desirable characteristics for this service:

(1). Positive volumetric discharge from the bin;

(2). By its motion it tends to make the bin discharge uniformly on all sides;

(3). Subject to adjustment in two ways:

  (a) Height of discharge gate;

  (b) Speed of disc;

(4). Mechanically simple, requiring only one bearing for support;

(5). Subject to multiple control, as any number of feeders may be geared together in positive operating unison;

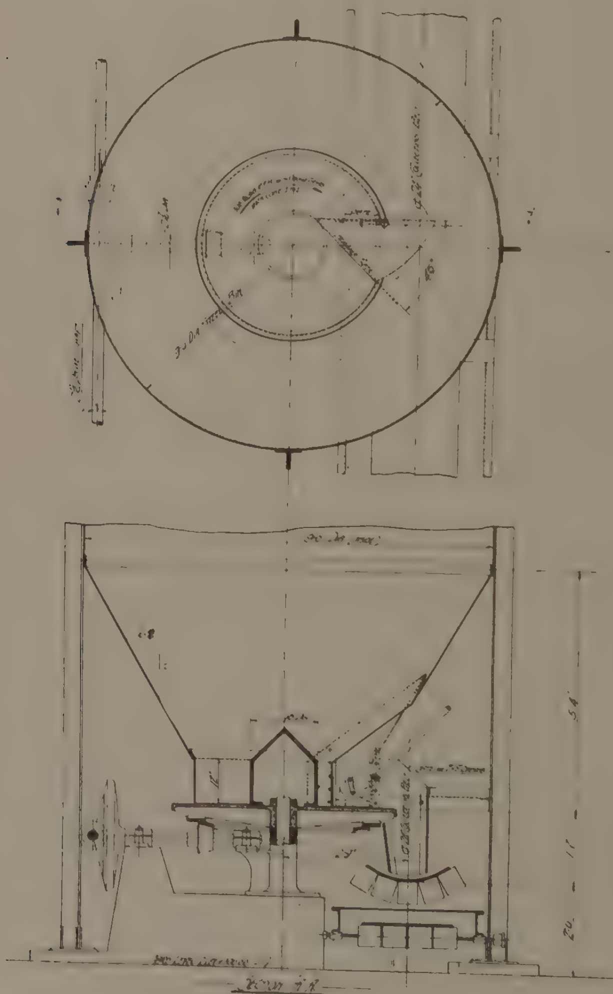

FIG. 3.—Revolving disc feeder.

(6). Very slow moving, which is conducive to lowest cost of mechanical maintenance.

Mixing Devices.

For accurate mixing of the proportioned materials several devices are on the market. We have, however, developed a pug mill which handles and mixes any materials satisfactorily, whether plastic or granular. All gears and bearings are made practically dust-tight; the wearing portions of the blades are changeable; with very slight expense and loss of time the shaft carrying the blades may be removed bodily without disturbing the bearings, and the bottom may be dropped for cleaning, while running. Thus for moderate expense a mixer embodying all desired characteristics can be provided.

It is the custom in the design of our sintering plants for the pug mill to be placed immediately preceding the delivery of the material to the sintering machine. This permits immediate adjustment of moisture content of the sintering mixture. This is a most important factor in operation as a slight change in the physical quality of the material will require immediate adjustment of the moisture content of the mixture in order that the sintering be maintained at the highest degree of efficiency. With slight training an operator may note, immediately after the ignition, a change in moisture requirement of the sintering mixture, and, by means of valves on the pug mill water supply, effect the proper adjustment of this item in five minutes of operation.

Distribution of Materials on the Hearth.

For making a perfectly uniform distribution of the mixture over the entire hearth area, we have tried out in actual practice a number of devices, too numerous to mention and not of present interest. The simple and effective swinging spout has solved the problem very satisfactorily. As the line of pallets moves in a continuous straight line, the swinging spout moving across this line of pallets, maintains the uniform deposition of the sintering mixture. In this way changing continuously the direc-

tion of the entire stream gives uniform structure to the entire bed.

When treating a highly variable material such as flue dust, it is necessary to change the depth of this layer from time to time, as changes in the characteristics of the flue dust demand. There is always some critical thickness of charge for any specific material at which the greatest quantity and the best quality of sinter is produced. The system of bins and proportioning feeders, mentioned before, will readily strike the best average of the sintering mixture, when the material is fairly uniform, and hence the depth of charge can be held constant; but when flue dust is the material treated, it will be found to vary from day to day in fineness, so that the thickness of layer at which the best sintering is performed will vary fifty to one hundred per cent. Operators should watch carefully such changes and make necessary adjustments for the same.

The super-hopper, which is above the pug mill, is in no sense an auxiliary storage, but is simply a feeder, the function of which is to hold enough material to maintain the sintering layer at a given depth. In order to prevent undue surcharge in this hopper, which interferes with the regularity of feed, it is very essential that the quantity of material delivered to the sintering machine be exactly its capacity, under existing conditions. The feeder or group of feeders which deliver this sintering mixture must synchronize with the speed of the pallets. Obviously the solution of this requirement is to gear the feeders and the sintering machine together. The absence of any transmission elements conducive to slippage is desirable, because the synchronism must be positive in order to be of value. This arrangement is used where the sintering mixture is delivered to a super-hopper after being proportioned, and where the moisture requirements of the mixture must be changed to conform to changes in the raw material. Flue dust is one material especially referred to in the latter statement.

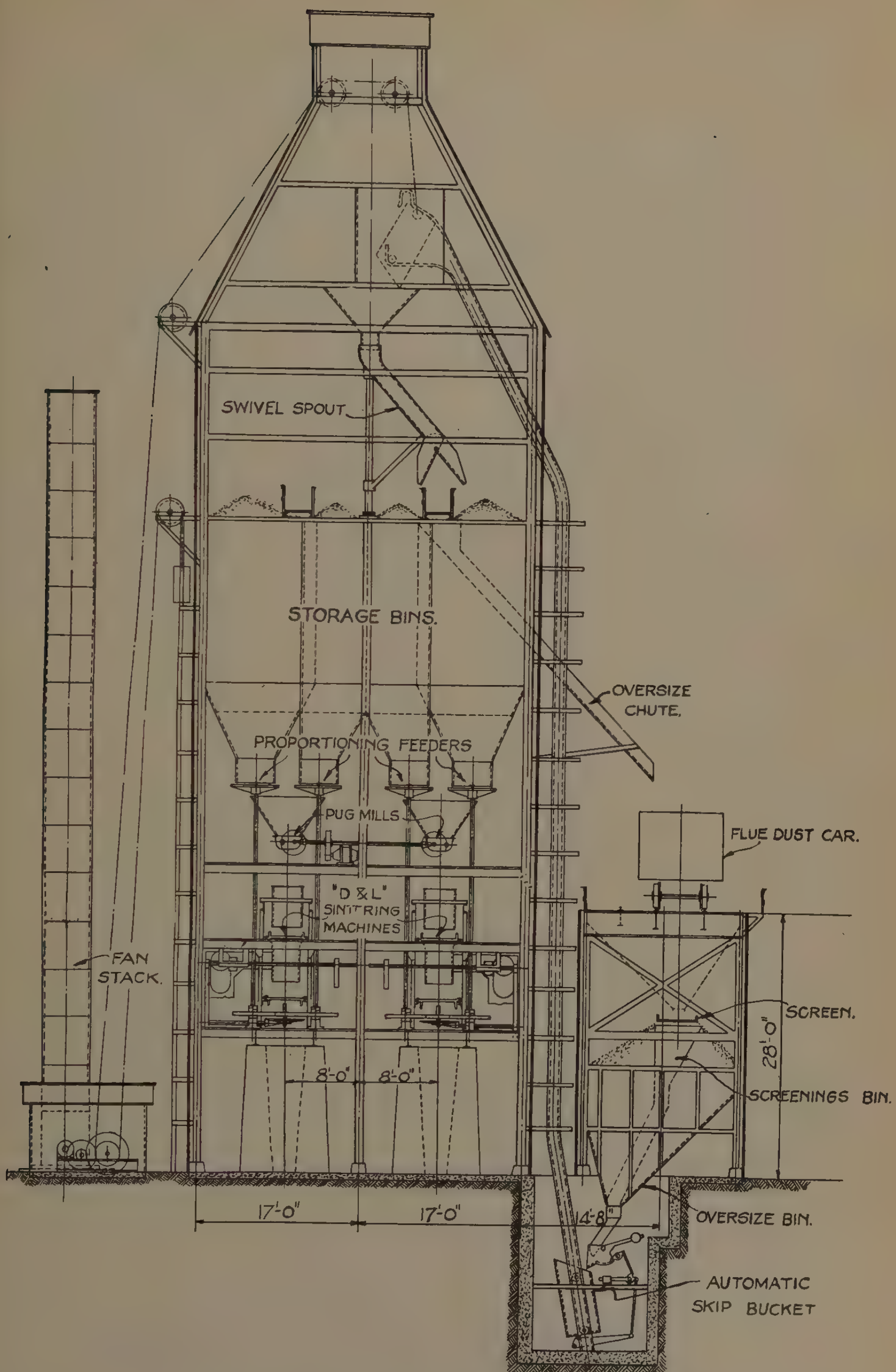

FIG. 4.—Dwight and Lloyd sintering plant with elevated storage bins and automatic skip hoist.

Where the material to be sintered is of a homogeneous nature, such as ores or concentrates, the pugging may be done immediately following the proportioning feeders. In this case the super-hopper should be mounted directly above the sintering machine feeder, and the feeder is driven directly from the sintering machine gearing. This gives a very desirable arrangement in that the feeders are always in sight of the operator.

Figure 4 illustrates a plant that is now being constructed for the Toledo Furnace Company, Toledo, Ohio, in which elevated storage bins are located within the building structure and are filled by means of an automatic skip hoist. In this plant the feeders for proportioning the sintering mixture discharge directly into the pug mills; hence, they combine the functions of proportioning feeders and super-hopper feeders. It is necessary that these feeders maintain the desired proportions accurately, and at the same time be subject to positive synchronism with the hearth speed of the sintering machine. This is accomplished by using an adjustable speed motor which drives an adjustable speed counter-shaft. The sintering machine is driven directly from the usual constant speed pulley, and the feeders, in unison, driven from the adjustable speed counter-shaft. The result of such arrangement is that when the various feeder gates are set to give a definite mixture, these proportions are maintained accurately, while the volume is varied at will by decreasing or increasing the speed of the feeders as set. It is noted that this set of feeders are driven by a compact and simple set of gears, any one or more of which feeders may be stopped at will by means of individual clutches. The feeders will all synchronize with the speed of the pallets, while when desired they may have their speeds changed independently of the sintering machine.

Proper Intensity of Ignition.

The next function performed upon the sintering mixture is the ignition. This ignition must be of ample in-

tensity to positively ignite the entire surface of the charge and yet not so intense that it will dry out the charge. In the latter case the sintering mixture is prematurely dried and the sintering action retarded, with incidental curtailment of output. Occasionally materials are encountered which require only very light ignition in order to produce the greatest sintering speed, while other mixtures will give best results under an ignition so intense as to leave an incipiently fused surface on the charge. No phase of this sintering art has passed through so many vicissitudes as that of ignition. Starting with a light gasoline torch, on our initial plant, we have passed

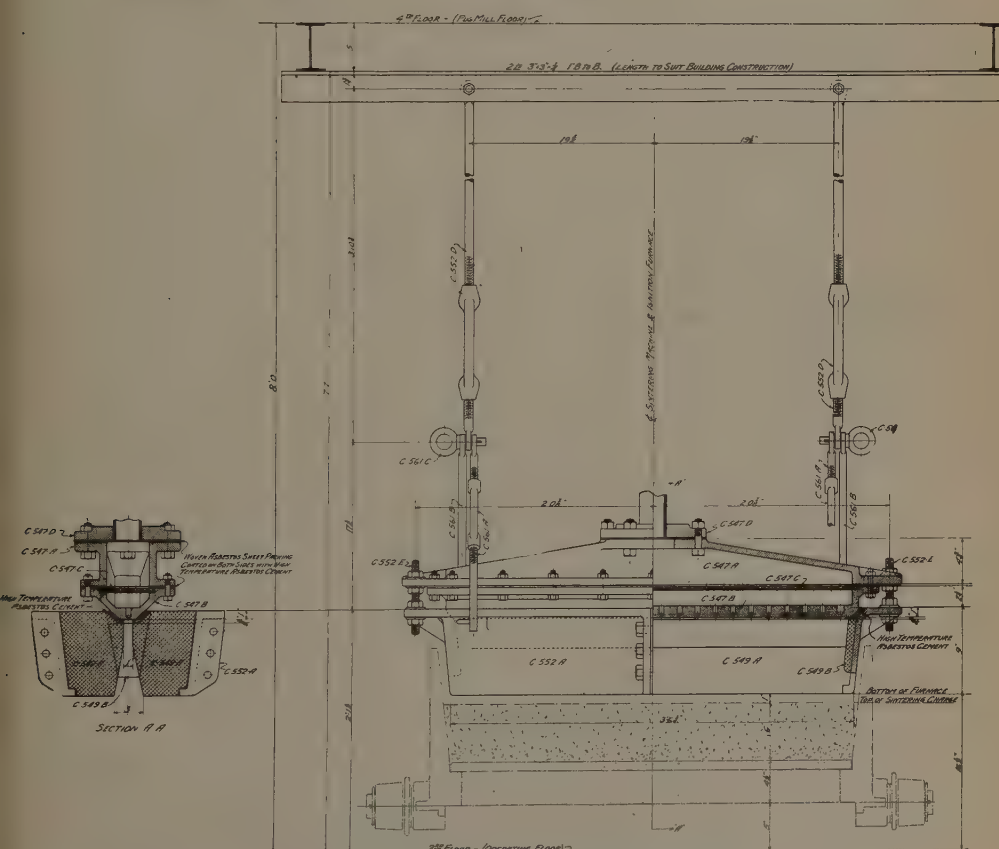

FIG. 5.—Blast furnace gas ignition-burner.

through many types of burners employing fuel oil, kerosene, bituminous coal, coal gas, natural gas and blast furnace gas.

Figure 5 shows the ignition burner now in use, which fulfils all requirements for effective ignition, viz., adjustability, durability and economy of fuel. The present burner is of a lower first cost than any of the previous types employed. It is interchangeable for natural gas, illuminating gas, blast furnace gas or fuel oil, simply by change of mixers. With this burner there was accomplished the use of blast furnace gas as an ignition fuel with no mixture of other fuel whatever. Blast furnace gas has been used without any trouble or delay whatever for practically two years, effecting a very important economy in sintering.

Exhaust Fans.

Up to the present time the suction for sintering has been produced by means of exhaust fans. A number of different types of fans have been tried and are still in operation. Fan engineering being a branch in itself, involving the control of many variables, there will be no resumé here of the vast amount of technical data collected relative to this work. Fans of larger diameter with low speeds have given better results than smaller fans at high speeds. The type of fan now giving satisfaction and which is recommended for pending installations is about 100 inches in wheel diameter, running at 600 to 720 R.P.M. and capable of handling about 20,000 cubic feet of gases per minute. The continuous nature of the Dwight and Lloyd process maintains a constant load on the fan, which is decidedly advantageous to the use of fans of large capacity.

Sizes of Sintering Machines.

The Dwight and Lloyd Sintering Machine is made in three sizes, to meet the varying requirements:

(1). Small size........ 42 inches × 13 feet.
(2). Intermediate size.. 42 inches × 25 feet.
(3). Large size........ 60 inches × 30 feet.

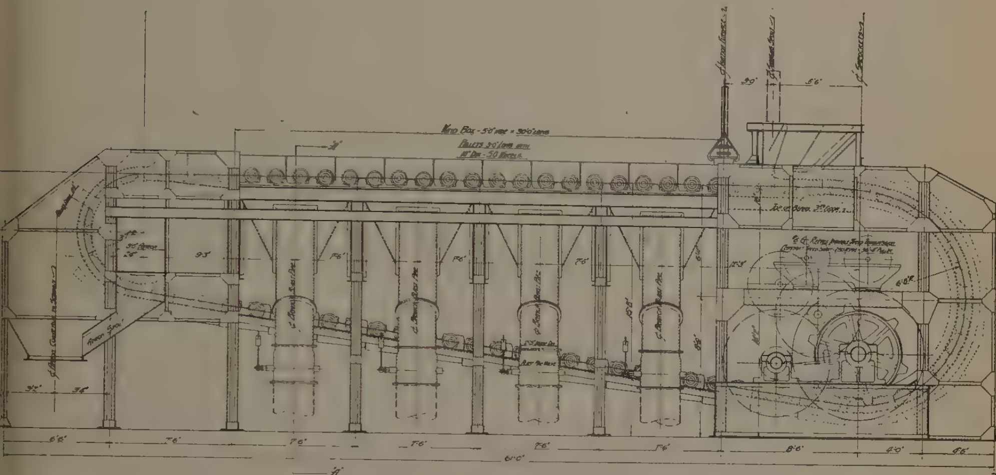

FIG. 6.—Large Dwight and Lloyd continuous sintering machine.

The small size can be converted into the intermediate size by simply lengthening it, if it becomes necessary to make a larger output. This small size is designed for plants where the available material for sintering is from 50 to 100 tons per 24 hours. The intermediate size, now in very extensive use, will provide a daily output of 100 to 250 tons, depending upon the material treated.

The anticipation of sintering some very large tonnages of materials has shown the need for a larger size machine. A convenient and practical size which fulfils engineering requirements is the one shown in Figure 6. This machine has a hearth area 70 per cent. greater than the intermediate size and has a daily capacity of 300 to 400 tons per machine, according to the material treated. The design of this machine is more simple and much stronger in its parts than the machines previously built. These three sizes provide equipment for any capacity of sintering operation desired.

Increase of Output by Auxiliary Apparatus.

The results of the careful study of all the details involved are shown in the fact that the original product per square foot of hearth area has been in some cases trebled. A sintering plant built for operation upon pyrites cinder had a capacity, based upon work done at the initial plant, of 75 tons per day per machine, but has now reached a production of over 200 tons per day per machine. Another plant constructed for a capacity of 75 tons per day per machine from flue dust, is making an average of 170 tons per day per machine. The first machine installed was of the same size as all of the machines now in use. In its first year of operation it scarcely exceeded an average of 50 tons of product per day. After being re-equipped with auxiliary apparatus, as good as local conditions would permit, it now exceeds 150 tons of product per day, and is successfully treating ore carrying sulphur. Since the first installation of the Dwight and Lloyd machines for the treatment of iron bearing materials, four years ago, and without changing the size of the machine, its daily capacity has been increased over 200 per cent. and its ultimate capacity has not been reached. In existing plants there are noted improvements which can be made, and from which continued development is confidently expected.

Advantage of Adding Fine Ore to Mixture.

The betterment of the finer grades of ores at existing mines is worthy of attention. Many of the Mesaba Range mines carry ore that is objectionably fine for furnace use. If these ores were mixed with flue dust, and the surplus carbon in most of the flue dust make, utilized for sintering the finer ores, the cost of so treating the ores would be nominal. Take for example a supply of flue dust that carries a carbon content double the amount that is necessary for sintering, and assume that the quantity treated daily is 100 tons. To this flue dust could be added an

equal amount of fine ore and the total expenditure for sintering operations would be practically the same for treating 200 tons of the mixture as for 100 tons of the flue dust. The flue dust, being a waste product, requires a certain expenditure per ton to reclaim it as sinter, while the fine ore, being new material and costing the same per ton as first-class ore, can be converted into a product in every way as good as the most desirable ore, at practically the cost of conversion assessed against the flue dust sinter alone.

The sintering and desulphurizing of fine ores and concentrates is daily opening into a wider field. The fear that with the development of the iron industry and the increased consumption of ore, that much leaner ores must be used, is obviated by the use of the sintering process. There is probably more metal disseminated through rocks carrying 35 to 40 per cent. iron than in the known rich deposits in this country, and this can readily be reclaimed. The concentration of these magnetic ores has in many cases produced a product which, while rich in iron, has also been so fine in size as to make it undesirable for blast furnace use; but the sintering of these concentrates converts them at low cost into a mass, cellular in structure, rich in iron and highly desirable for blast furnace use. The relation of fine ores to sinter is best described as that of flour to biscuits, and in each case the treated product is more readily digested. The waste paint rock of the Mesaba mines, carrying 22 per cent. water, responds readily to sintering and yields an ore with 52 per cent. iron. There is a large annual tonnage of burnt pyrites which can be converted by sintering into a valuable ore, and when the copper is objectionably high, it can be leached out before sintering. It is evident, therefore, that the development of the sintering process secures to the iron industry a supply of rich ore for a long distance into the future. (Applause.)

President Gary: Discussion led by Mr. Robert E. Brooke, of the Brooke Iron Company.

THE MECHANICAL DEVELOPMENT OF SINTERING OF IRON BEARING MATERIALS

Discussion by Robert E. Brooke

Treasurer, E. & G. Brooke Iron Company, Birdsboro, Pa.

My remarks on Mr. Klugh's paper will be chiefly in confirmation of what he has said in regard to the appliances which have increased the tonnage of sinter from iron bearing materials over the amount expected in the beginning.

The first sintering plant for treating iron flue dust was built at our furnace at Birdsboro in the summer of 1911 and started its operation in October of that year, to sinter the flue dirt accumulation there.

The machine was of the then standard size, 42″ x 22′, and the tonnage hoped for was 75 to 80 tons per day of 24 hours, but not nearly this amount was reached, the average daily product being more nearly 40 to 50 tons per day. For instance, in November, 1911, the average amount produced per operating day was 50 tons, and in December 51 tons. In January, with 28 days running, the output averaged 44 tons, which was good, considering the winter conditions. In February we made 41 tons per day. The best daily tonnage for the plant, reached 65 tons in the 24-hour run on flue dirt, but that was a high record.

Mr. Klugh was in charge of these sintering operations and the great variability in flue dirt composition and the other difficulties in mixing, feeding and ignition, were presented to him and largely overcome by his experiments at this plant. As we, of course, wished to increase our product of sinter, we took the matter up with the American Ore Reclamation Company, engineers, and at their suggestion, last winter, installed a

larger elevator, capable of carrying 300 tons daily, instead of 100 tons, which was the best the old elevator could do. We also put in a super-hopper, into which the present elevator feeds the material. This super-hopper holds about an hour's run and its use tends to mix the material more thoroughly, and with the feeder at the bottom we obtain a good, steady layer of material running to the new double-shaft pug mill, which has a much enlarged capacity over the old one. From the end of this pug mill, the ore drops directly into a swinging spout, which gives it a much better distribution as it reaches the pallets. In the receiving hopper below this spout, a deflecting plate at an angle of 45 degrees breaks the fall, thereby preventing the packing of the material on the grates and sending the larger particles to the bottom of the layer on the pallets, leaving the finer on top. The finer material contains the finer particles of carbon and makes uniform ignition more easy. We find it of advantage that as little material rest in this receiving hopper as possible. We formerly used fuel oil for ignition, but are now using illuminating gas and within the next week or so expect to use blast furnace gas.

The above changes have enabled us to increase the speed of the moving pallets from about 12″ per minute to 19″ and 20″, and the thickness of our layer from 4″ to 5½″. Our fan has not been changed as yet, being the original 66″ diameter wheel installed, but we have increased the speed from 700 to 900 revolutions per minute, which is about the limit of our motor. We have put in a new stack 150 feet high, to carry off the sulphur fumes.

In this connection, it is only fair to say that we are not running at present on flue dirt, except as we use it in the mixture to give us the carbon required for sintering fuel. The sinter we are making is derived from a high-sulphur magnetic ore which we crush in a Buchanan crusher and in rolls and then pass through a

3/8″ screen, the sulphur running over 3% in the crude ore and being reduced by sintering to a maximum of .21%. The sinter comes off the pallets in large cakes and seems to work very satisfactorily in the furnace. The sulphur can easily be reduced further by crushing the material finer, but the present content is not found to be objectionable in the furnace.

The product from the sintering machine for the 11 days from October 4th to 14th, inclusive, has been 134.8 tons per day of 24 hours. We expect to make over 4,000 tons this month. When we do not have enough flue dirt for admixture with the ore, we use screened coke dirt, the sintering mixture requiring only about 5% of fuel. We do not believe we would obtain this tonnage when running on flue dirt alone, with our present equipment.

To further increase our tonnage, we are about to install a new American Blower Company double-inlet fan, with a 100″ diameter wheel, which is on the ground, because it seems clearly proven that larger tonnages are in proportion to the volume of wind. With this fan, we confidently look forward to obtaining 250 tons of sinter per day. When the fan is installed, we shall have to raise the sides of our pallets about 3″, which will enable us to use a thicker layer.

In the summer of 1913, we saved up some of this sintered ore and made a test of a two weeks' run on practically 25% of the furnace mixture. As the sintered ore contained 55% iron, we decided to substitute it for the following ores:

2/16	Old Range ore,	running	48.47
1/16	Coarse Mesabe	"	52.37
1/16	Pt. Henry Con.	"	65.00

The Port Henry Concentrates brought the average iron contents of replaced ores up to 53.53%, which was of course 1.5% below that of the sintered material, for this 1/4 of the mixture, the rest of the mixture remain-

ing unchanged. For the four weeks preceding the test, the average fuel was 2,130 lbs., railroad weights, ore yield 56.53%, product 6,833 tons of Basic iron, or 1,708 tons per week. We started to put the sintered ore on the week of August 17 to 23, which is included in the last figures, as only 6.4% of sinters were used, in that one week. The following week, we had 21.44% of sintered ore on, replacing the other ores mentioned above, and our fuel per ton of iron was 2,080 lbs., railroad weights, yield 59.40%, product 1,715 tons, and the week of August 31 to September 6, we had the full 25% of sintered ore on, and the fuel was 2,070, railroad weights, yield 58.64%, and product 1,707 tons.

As mentioned above, the average actual yield for the four weeks preceding the test was 56.53% iron. With the increase in iron contents by putting on 4/16 of the mixture of sinter, running 55% iron, against the replaced ores running 53.52%, the ore yield, increasing in about the same proportion, would have been 56.90%, whereas it actually went to 59.40% and 58.64%, respectively, for the two weeks of the test, closely approaching the theoretical yield, and showing that the Sinter had not blown out through the downcomers nearly as much as the replaced ores.

At present, we have in our mixture:

6/16 sintered ore;
7/16 N. J. and N. Y. Magnetic ore;
2/16 Manganate;
1/16 Heating Cinder, mixed with a little roll scale.

We have had this mixture on for about three and a half weeks. The first week mentioned, ending October 2nd, we made foundry iron, 2X chiefly, and the fuel was 2,207 lbs., railroad weights, yield 61.93%, and the product 1,589 tons. The second week mentioned we changed to basic, but the furnace being overblown during the early part of the week, made some white iron and the engine had to be pulled back. The product was 1,688

tons and the fuel 2,044 lbs., railroad weights. The furnace had received, however, some extra scrap during the above two weeks.

The third week, ending last Saturday, October 16th, the furnace steadied down on basic, making no misfit. Our fuel was 2,199 lbs., railroad weights; our limestone was 29.3% of the ore. This ore mixture contained 55.50% metallic iron. The actual yield was 58.59%, again approaching the theoretical yield. The furnace has been doing better work over the last ten days or more, the burden having been gradually increased from 13,600 lbs. to 14,800 lbs., and at the same time we have gradually put our engine up from 19,500 cu. ft. to 20,750 cu. ft. per minute, with increasing daily tonnages. During the period mentioned, from October 9 on, the furnace has not been receiving any extra scrap, so it is evident our ores are staying in the furnace.

For the first four days of this week our product has been 252 tons per day, fuel 2,120 lbs., railroad weights, ore yield 58.40%, and stone 27% of ore. All the casts were standard basic iron.

Our experience, thus far, with the sintering proposition certainly leads us to believe that the product is equal to that of a high grade ore. (Applause.)

President Gary: The discussion will be continued by Mr. H. A. Brassert, of the Illinois Steel Company.

MECHANICAL DEVELOPMENT OF SINTERING OF IRON BEARING MATERIALS

DISCUSSION BY HERMANN A. BRASSERT
Superintendent Blast Furnaces, Illinois Steel Company, South Chicago, Ill.

The paper just presented shows how many intricate problems may present themselves in the working out of a simple process, and gives a clear idea of the progress which has been made in developing the continuous down-draft sintering machine through carefully working out, step by step, all of the mechanical requirements of the process. Mr. Klugh and his associates are to be congratulated on their success and the state of perfection to which they have brought the Dwight-Lloyd method.

Here, too, "Necessity has been the mother of invention." Flue dust is, of all materials, the most difficult to handle, and on account of the low value even of the sintered product, the cost of treatment must be kept at a minimum in order to make the process commercially feasible. A number of processes have demonstrated the possibility of agglomerating such material through sintering and making a product suitable for blast furnace use, and the sintering problem has resolved itself largely into one of cost of installation and operation. This in turn has narrowed the choice, at least for the sintering of flue dust, down to two processes: the down-draft and the rotary kiln. Each has experienced variations in the mode of operation. In the case of the former we have witnessed the development of the continuous and the stationary methods; in the latter, that of the plain kiln with intermittent operation and of the kiln equipped with chain scraper, permitting of continuous operation, as well as the most recent invention known as the Downs Tuyere Process.

My intimate practical experience has been with the

chain cleaned rotary kiln. The one at South Works of the Illinois Steel Company was the first of its kind installed, and has been successfully operated for the past ten years.

Comparing the two processes, the down-draft process has the advantage of minimum cost of fuel and low cost of installation. It uses no outside fuel except that for ignition, and depends on the carbon content of the dust alone for the heat required to accomplish sintering. For that reason it is sensitive to the variations in chemical analysis of the dust, particularly of the carbon content, and hence the importance of correct proportioning and thorough mixing of material to give a charge of advantageous and regular composition. The necessity of distributing the draft evenly through the entire bed of material, calls for a high degree of physical uniformity. Through establishing the proper relation between the thickness of the bed and the fan suction, the rate of sintering has been greatly accelerated. It is through the careful study of these essential details that large outputs of uniform quality are being made at a very low conversion cost by the down-draft process.

The rotary kiln, on the other hand, uses more or less external fuel, and it is for that reason that the process is not as sensitive in regard to the varying qualities of the flue dust. The kiln is mechanically the simplest sintering device, and like the Dwight-Lloyd, serves at the same time as conveyor for the material through the process. With the plain kiln, the main difficulty has been the building up of sintered material on the walls. These ring-shaped accumulations have to be removed at intervals, unless the walls are permanently kept clean by means of a scraper chain. This chain is an essential accessory, since it eliminates the shut-downs, even when flue dust only is used, except for relining of the kiln, which at South Chicago has to be done two or three times a year. The largest cost item is the fuel, although we have been able to decrease it to some extent by pre-

heating the combustion air and by localizing the zone of combustion through modification of the burner. The best remedy, however, is apparently the Downs Tuyere Process, which forces air under pressure through the shifting bed of materials near the end of the kiln, and thereby burns out the carbon, thus utilizing its heat in a similar manner as is done in the down-draft process.

In all methods a regular carbon content of from 6 to 8% is of the greatest advantage. In fact, with a high and irregular carbon content no plant has been able to show as low a conversion cost and to make as satisfactory a product as a plant using good dust. It appears quite likely that out of the necessity to regulate the percentage of carbon, rather than of the impossibility to successfully smelt Mesaba ores and roll scale in their raw state, a portion of such materials will in the future be added to the flue dust and sintered with it.

Among the fine materials to be considered for sintering, those should naturally be chosen first which are present at the blast furnace and steel plants, and have to be disposed of. Next should come such fines which are produced as heads or wasted in the tailings in the various wet or dry processes of ore beneficiation; and last, the sintering of a portion of the ores themselves should be considered.

As a material of the first class, the sediment from the discharge of our gas washers demands our special attention. This so-called "pond sludge" is of the greatest physical fineness, is sufficiently high in iron, and on account of its uniform composition should lend itself well to admixture with flue dust. That method which can be adapted to handling this sludge in the most economical manner will have an important place in the future development of sintering. It should, however, always be borne in mind that it is not profitable to treat materials which contain such elements as are detrimental to the furnace practice or to the quality of the iron, and cannot be removed in the process of sintering.

Many materials are of too low a value to bear the cost of sintering. Neither is it economical to sinter materials which, in spite of their fineness, can be used without difficulty in their raw state. As long as the standard grades of Mesaba ores can be smelted in their natural condition with such good results in regard to regularity of performance, uniformity of product, and low fuel consumption, as is the well-established practice of many blast furnace plants to-day, it is obviously not necessary to sinter them. But an increasing tonnage of low grade ores will be mined from year to year, and much of this must be beneficiated by various processes before being shipped to the blast furnaces. A percentage of concentrated fines is produced in this treatment which should not be mixed with the coarser heads, but should be kept separate and put into suitable shape for blast furnace use. In view of their high grade, and their physical and chemical uniformity, they form an ideal material for sintering, and open a new and important field for the future development of sintering processes. (Applause.)

President Gary: Open discussion is now in order. Are there any volunteers? (After a pause.) "Under-Advertising of the Steel Business," by Mr. George H. Jones, Vice-President, Inland Steel Company, Chicago, Illinois.

UNDER-ADVERTISING OF THE STEEL BUSINESS

George H. Jones

Vice-President and General Manager of Sales, Inland Steel Company, Chicago

England has raised the greater part of an army of four millions by advertising, using newspapers, bill-boards, omnibuses and other methods. This was considered the most effective way and its application is almost universal.

This is an object lesson to the iron and steel manufacturers who have been in the habit of saying about advertising, "When the demand for our products is good there is no need for it, and when the demand is poor there is no use of it."

The steel manufacturers can pave the way to make depressions less severe by stimulating a demand for the products of the steel mills. The way many of us advertise is to place what amounts to a business card in a trade paper and let it go at that. It will do once in a while to call attention to a full list of our products, but it possesses little sales value. We want our advertisements to be read. We must, therefore, give truthful information of value to a prospective customer, and whenever possible the matter should be well illustrated. One product only should be treated in one advertisement. Sizes, quality, capacity and other special advantages we have to offer should be stated and enlarged upon. We should answer the readers' questions before they are asked.

Advertising Agencies.

Very few of those who have advertising in charge have the time or inclination to do this work properly. It requires much watchful detail work, knowledge of the

printer's art and getting the copy to the publication at the proper time and *ready* for printing. An advertising agency can do this well at a comparatively small cost and it brings in a trained mind and another viewpoint. When you consider what you pay annually to the publications in which you advertise and the aggregate of all, it is worth the small extra percentage which it costs to have much of the work done by an expert. This cannot be entrusted to the publications themselves, who offer to do it without charge. With the best intentions, they cannot solve the problems of their advertisers, nor do they have the necessary technical or other knowledge to do it. Their methods are more or less stereotyped and lack the knowledge to carry conviction. The practice of accepting this free copy service from newspapers has the added disadvantage of destroying all unity in the campaign.

Trade and technical periodicals must not be neglected in making out an advertising programme. A certain amount of general publicity is also necessary, and the public must be informed of the merits of any special product, in order that a demand be created for it, without which the dealer and manufacturer would not ask for it. Pamphlets, booklets, folders, cards, circulars and letters can be successfully used. The personal call is often necessary and the outdoor field could be used to advantage. Catalogues that give some real information and explanations are badly needed. Too often they only represent the mill man's viewpoint and give the buyer very little of the facts and figures he needs. Catalogues are recommended to be of uniform size—$8\frac{1}{2} \times 11$ inches and preferably issued in separate divisions covering kindred products.

Creating Demand for Steel Products.

The use of structural steel is due to a demand for it rather than to any effort made by the steel manufacturers to introduce its use. But steel bars for reinforcing concrete are required in the main as a substitute for other than steel construction because the cement manufacturers

and the concerns controlling patented bars promoted a large use for their products and in doing so these bars came into being, in spite of rather than because of the steel makers themselves. The tonnage of concrete bars now made by steel manufacturers is of considerable importance to the industry.

At the May meeting of the Institute Mr. Edward M. Hagar said:

> If the manufacturers of steel spent as much money to instruct the people in new uses for steel as the manufacturers of cement in proportion to the dollars of business done, the steel men would be spending $12,000,000 a year to extend the uses of their own product. That $12,000,000 would represent only a fraction of a cent of each dollar's worth of business done. We cement manufacturers have found by experience that we get back with big interest all the money we spent in this educational campaign.
>
> The cement manufacturers are helping the steel manufacturers in this direction. Reinforced concrete calls for steel rods. Iron and steel producers and the cement manufacturers might find it mutually advantageous to co-operate in this educational work.

The Association of Sheet & Tin Plate Manufacturers last year started a Bureau of Development which promised well, but it did not materialize owing to the "penny-wise and pound-foolish" ideas of many of those to whom it should have appealed and who were invited to co-operate. Enough subscriptions were not received to justify them in going ahead with the very full and comprehensive programme outlined in their "Memorandum of Plans." In this pamphlet Elbert Hubbard is quoted as having written:

> Not long ago I visited a State Hospital for the Insane.
>
> Walking over the beautiful grounds half a mile from the main building I came across an attendant in charge of twenty-five patients.
>
> The attendant was a little man, a sort of half portion. Many of the patients weighed twice as much as he.

I walked along with him for some distance and in the course of our conversation I said: "I don't want your job. What is to hinder half a dozen of these big fellows getting together and setting up a job on you? If they would get at you all at once you would not stand any show at all. There is no help within half a mile and you are not armed."

He looked at me in rebuke and remarked: "You belong here, all right! You ask what is to hinder these fellows getting together and setting up a job on me? Why, the fact is, if they could get together with anybody or anything they would not be here. That is their trouble. Nobody is ever sent to an insane asylum who can do team work."

The badge of sanity is the ability to co-operate with other people; and the more people you can work with and for, the bigger and better you are. It is an age of organization.

Competition may have been the life of trade once, but it is no longer so. Competition died when the inventive genius of American engineers devised machines that should manufacture beyond the present economic wants of the people. Competition then became suicidal and destructive, and anything that is suicidal is dying—dead.

Simply because one is in the same line of business as another man is no reason why he should attempt to destroy him. A certain amount of mutuality is absolutely necessary to live.

Elbert Hubbard was not a steel man, but he was, nevertheless, about right with regard to the lack of co-operation in promoting the steel business.

Example Set by Lumbermen.

About six years ago five men in the south each put up \$260 into a fund to advertise red gum in an architectural journal, after dint of much hard work on the part of a representative of that journal.

Though they were men of wealth, this \$260 came hard because they really did not believe that anything would come of it.

But the result of that \$1,300 venture was the sale of

red gum aggregating $350,000 with three successive $2.00 jumps in price per 1,000 feet in a single year. This campaign has continued year after year, as high as $40,000 a year being spent in it. The result is the widespread use of red gum wood for fancy interior finish—a wood that had previously been in the railroad tie class.

This campaign started the Southern Cypress Association into action, and their annual advertising expenditure far exceeds that of the Red Gum Association.

Then came the North Carolina Pine Association, the Northern Pine Association, the West Coast Lumber Manufacturers Association, the California Redwood Association and, last and largest of all, the Southern Yellow Pine Association. There is now talk of an amalgamation between all their interests for the purpose of financing a mammoth campaign in favor of wood as against "substitutes" for wood.

Let us acknowledge that, as a class, the steel industries of the country are the most clumsily and inadequately advertised of all our industries.

I almost feel safe in saying that more advertising money has been spent in *tooth paste* than all of us combined have expended in all of our products.

And our total expenditure would look like small change beside the bank roll expended annually by the chewing-gum profession, the soap artists or the baking powder family.

Yet steel products as a group are just as susceptible to the power of publicity as any of these; because just as universal in consumption and vastly more important to the public welfare.

Result of Advertising Hawaiian Pineapples.

Up to 1909 the importation of pineapples from the Sandwich Islands was so inconsiderate that they were not even listed in the government reports.

But about that time thirteen leading producers formed an association and placed in the hands of Mr. Dole, son of

a former president of the islands, about $100,000 with which to educate the American people to ask for Hawaiian pineapples.

Successive reports show the following importations:

Exports from Honolulu—canned pineapples and pineapple juice—

1910	$1,558,507
1911	2,244,931
1912	2,704,446
1913	3,644,794

The point is that that intelligent campaign carried on year by year not merely diverted the trade away from Cuban and Bahaman pines, but it multiplied the *total consumption* of pineapple products to a degree not even faintly hoped for by the Hawaiian growers and canners.

New Fields for Steel Products.

Similarly, an educational campaign on steel products will not only serve to protect us against the onslaughts against us made by various substitute products, but it will lead to a great total increase in building operations. Just one case in point: a million farmers now leave their implements out in the fields all winter unprotected by *any* shelter—steel, wood, paper or otherwise. Our duty to ourselves and to the farmers is to stop this ruinous loss by first showing them their folly, and then giving them practical instruction in the way of stopping that loss by erecting sheet steel shelters.

Another instance: Cash wheat at harvest time averages some cents per bushel lower than its selling price in mid-winter or early spring. This is simply because farmers, with no place to store their wheat, sell it to the local elevators at whatever price they offer. Our duty is to show the farmers how they can vastly increase their earnings by erecting inexpensive steel grain houses and storing their grain on their own farms until demand has caught up with the supply.

Still another typical example: shelters at cross-road stops of interurban trolley lines. The right sort of an educational campaign will show these roads how they can increase their traffic by providing this comfort; and if they don't do so, such a campaign will wake up the farming public to demanding it.

No doubt hundreds of other fields lie open to us if we will but learn the vital necessity of harnessing the vast willing and responsive power of educational publicity. The same sort of organized publicity has been done with other products, among which may be mentioned electrical machinery and equipment, gas making machinery, etc.

Fire Prevention.

The Association of Sheet & Tin Plate Manufacturers in April, 1914, issued a pamphlet entitled "A Discussion of Fire Prevention in Its Bearing Upon the Use of Non-Inflammable Materials." I quote a few pertinent paragraphs.

Nobody can deny that if all buildings were made absolutely fireproof and everybody continually careful, we might save most of this stupendous amount of wealth now wasted annually.

It is a worn out fallacy which assumes that the fire loss is borne by the insurance companies. They bear no loss but act merely as collectors and disbursers. The losses are a tax on every man.

The cost of maintaining fire departments in European cities is about 25 cents per capita per annum, while in American cities it is \$2.57 or 10 to 1, and the cost of fire loss and fire fighting combined averages in European cities 58 cents per capita per annum, while simultaneously in America it costs \$5.07 or at the ratio of 8¾ to 1. This difference is due almost entirely to better building conditions.

It has been estimated by the underwriters that 27 per cent. of the fire loss in this country comes from fires that extend beyond the buildings in which they originate.

A reasonable conclusion is that losses are due to the inflammable construction of our buildings.

Another writer states the loss by fire in some of the older European countries is only 2c per capita and in the United States $2.80 per capita or 140 times as much.

It is reported there are six million farms in the United States, 10% of which use metal roofing and 30% patented (not metal), and the remainder generally shingles, with perhaps a few tile and slate roofs. This condition can be changed by proper promotion work and patented roofing largely supplemented by sheet steel and tin. Some good work has been done along these lines, but not enough to make much of an impression. The question of fire and lightning comes in here. The perils of combustible roofs are well known, but often forgotten. They should constantly be kept before the owners of farm and other buildings.

The manufacturers of patented roofings, more or less inflammable, spend large sums annually running into the hundreds of thousands of dollars in advertising their goods and have been successful in getting them used, to our disadvantage.

Advertising has made the use of patented roofs possible and the mail order houses have been liberal and consistent helpers. These feltless "felt" and rubberless "rubber," inflammable, "fireproof" roofs have very little excuse for existence and metal roofing should take their place, besides encroaching largely into the percentage of shingles.

The National Hardware Association this year offered prizes for the best essays on "What Constitutes a Good Roof," from the standpoint of metal roofing. The three best essays have been printed in a booklet which is given a large circulation. This is a step in the right direction.

One phase in the extension of the sale of many of our products is the education of both wholesale and retail merchants, especially the retailers and their clerks.

By making them better steel salesmen we can multiply their sales. This is of vast importance because the aggre-

gate tonnage of steel and steel articles sold to the consuming public through retail sources is exceedingly great.

Lumber dealers are now selling steel fencing, steel fence posts and steel roofing. It is not natural for them to do this, but they are merchants first and lumber dealers afterward. They are, therefore, selling what is asked for, and we can help them materially to increase their sales of our products. Modern saw-mills, interested only in the production of lumber in its various forms, are using steel roofing and in doing so they admit it has advantages over their own product. It is fireproof, lightning-proof when properly grounded, and will last longer when taken care of than any of the materials heretofore used.

Field for Promotion of Steel Sales.

Promotion and sales work—comprehensive and extensive—is needed to further the use of steel in the following directions:

Roofing and siding of proper weight in place of patented materials.

Fence posts for railroads, farms, vineyards and other uses. There are probably fifteen to twenty concerns now making steel fence posts and they are commencing to do well, but the possibilities in this line have hardly been touched upon. In bolts—on account of the greater tensile strength and uniformity of structure. In many lines of work steel has come into its own and may be safely left as it is, but steel could be used in smaller sizes, giving equal strength and less weight, in the following items among others:

Metal Shingles	Steel Scaffolding
Metal Ceilings	Steel Warehouses
Steel Lath	Steel Warehouse Boxes
Steel Fire Doors	Steel Boat Houses
Steel Window Frames	Steel Storage Buildings
Steel Lockers	Steel Shops
Steel Culverts	Steel Tool Houses
Steel School Furniture	Steel Foundries

Steel Office Furniture
Steel Shelving
Steel Barrels
Steel Kegs
Steel Crates
Steel Packing Boxes
Steel Telegraph Poles
Steel Telephone Poles
Steel Railroad Ties
Steel Cattle Guards
Steel Wagon Bodies and Seats
Steel Wagon Tongues
Steel Double Trees and Single Trees
Steel Hay Racks
Steel Barns
Steel Hog Houses
Steel Chicken Houses
Steel Implement Sheds
Steel Grain Bins
Steel Corn Cribs
Steel Fruit Picking Stands
Steel Ladders
Steel Repair Shops
Steel Section Houses
Steel Oil Houses
Steel Gasoline Depots
Steel Garages
Steel Real Estate Offices
Steel Labor Dormitories
Steel Sectional Buildings for factory extensions, and other purposes
Steel corrugated sheets for tight fences
Steel frame work for small buildings
Steel Tanks
Steel Silos
Steel Boats
Steel Barges
Steel Burial Caskets
Steel frames and boards for standing signs
Steel for mine, timbering and tipple work for main and outbuildings

Co-operation of Steel Men in Promoting the Use of Steel.

Development work covering an increase in the use of steel in the various directions in which it could be employed to advantage, might be well undertaken by all steel manufacturers and through them by their customers under the direction of a Bureau of Publicity and Promotion of the American Iron and Steel Institute. This Bureau, acting for the interests of the steel business at large and not handicapped by being confined to the product of any one concern, would be on the watch to determine in what way steel could be substituted for other materials and be prepared to offer suggestions as to the best means to secure the results aimed at. The Institute being recognized as a responsible and authentic institution, could not afford to disseminate inaccurate or unreliable information, nor would it be suspected of doing so. It would be incumbent upon the steel manufacturers to carry out the standards

recommended by the Institute and not cater to the demand for underweight and cheapened material.

A series of handbooks on steel and its advantages, issued in sufficient quantities, under the auspices of the Institute and sold to its members at cost, for their distribution to the merchants with whom they deal would be most effective.

These might take the form of little pocket manuals such as were issued by the Cypress Association—a manual for each of some twenty general classes of building, structures or articles. Indeed this plan could be carried still further, the dealer being supplied with a sufficient quantity for him to distribute to his consumer customers, as has been done so effectively by the cement makers.

The booklets would be couched in very simple, non-technical language, with easily understood diagrams and illustrations.

The farms of this country offer a vast undeveloped market for a great variety of steel products. A concerted campaign by this Institute, in the influential farm journals, would bring very satisfactory results. This campaign might take the form of offering to the farmers their choice of booklets on certain farm buildings, as for instance silos, implement sheds, roofs, etc.

Such a campaign would involve the expenditure of a large sum in the aggregate, but the share of each member participating would not be burdensome.

I have made no mention of the possibilities in the export business, the exploiting of which is in a class by itself and should be treated separately by one experienced in that particular work. (Applause.

President Gary: Opportunity for open discussion is now afforded. This would seem to be a great opportunity for Mr. Penton and some others. (After a pause.) Has any one anything to offer on this subject? Mr. Kennedy, of Buffalo.

UNDER-ADVERTISING OF THE STEEL BUSINESS

Discussion by Hugh Kennedy

Vice-President, Rogers-Brown Iron Company, Buffalo, N. Y.

It seems to me that this Hotel Statler knows the power of advertising. While I was dressing this morning a newspaper was pushed under the door into my room. I called the office and said, "I have got some other fellow's newspaper." The reply came, "No, it is your newspaper." I have no doubt every one of you stopping here had the same experience. This is a little thing, but it leaves a good impression. We will tell our friends about it. I think we can also learn a lesson in advertising, in our offices, by observing the manner in which our patrons are received; whether in a disagreeable manner by an uncivil, impudent boy, or with the courtesy usually expected by them when making a call. The same is also true with regard to traveling salesmen; most of whom make you feel that "you are the people we are serving; we want to do more for you than you ask." It is the little things that go to make a good impression, and they are of value in advertising. (Applause.)

President Gary: Is there anything further to say in regard to the paper or to Mr. Kennedy's suggestion? (After a pause.) The next topic is "Development, Manufacture and Uses of Alloy Steels for Commercial Purposes," by Mr. Edgar D. Rogers, General Sales Manager, United Steel Company, Canton, Ohio.

THE DEVELOPMENT OF ALLOY STEELS FOR COMMERCIAL PURPOSES

Edgar D. Rogers

General Sales Manager, United Steel Company, Canton, Ohio

This subject covers such a wide scope that it seems advisable to limit this paper to a more or less historical and practical viewpoint regarding the development and use commercially of alloy steels, rather than to attempt a thesis on the technology of the subject, except in a most superficial way. Further, no attempt has been made to cover the field of strictly crucible steels for lack of experience in that process of manufacture.

The oldest alloy steels of which we can find record are an ingot of prehistoric times, analyzing 1.20% carbon, 1.60% silicon, unearthed near Nancy, and a tool containing a small percentage of nickel, removed in 1837 from the Cheops Pyramid. Also the Damascus steel of Toledo contained tungsten, nickel and manganese. There is no evidence that these steels were intentionally alloyed, but were the result, probably, of a combination of different element bearing ores. During the eighteenth century great advances were made in metallurgy, although the opinions on the subject were vague. The effects of phosphorus, sulphur, bismuth, tin, antimony and arsenic in iron were known about 1740.

Early Experiments.

It was not, however, until the first half of the nineteenth century, and then only after ordinary carbon steel composition had been determined by Reaumur, that the first intentional experiments to alloy metals with iron were undertaken. In 1812 Hassenfratz, under orders from Napoleon, completed his work on the effects of cobalt on iron. The effects of titanium, chromium and tungsten were also known about this time.

In 1819 Faraday, together with Stodart, attempted to produce experimentally some synthetic alloys, their object

being to obtain metals which would be more resistant to oxidation than common steels. They learned that iron alloyed with 2% silver proved an excellent metal for some types of surgical instruments. Experiments were also made by alloying platinum, rhodium and gold with iron; the platinum and iron producing a metal which, on account of its color and luster, proved excellent for metal looking glasses.

Berthier in 1821 discovered the excellent properties of chromium steel. Further experiments in 1829 by Berzelium developed an alloy of peculiar properties called Meteor Steel which contained zinc, nickel, tin and chromium.

About 1829 the first determinations of physical properties such as tensile strength were made also as to the effect of forging on the different steels, which brought to the attention of the trade the importance of homogeneity of steel. The wonderful development in the use of steam as a power served as an impetus to the steel maker for the production of better and more homogeneous steel, and the demand increased to such an extent that chemists and metallurgists turned their efforts to the production of a better and cheaper product. This brought about the invention of the Bessemer converter in 1856, which may be considered the birth of the present steel age.

This also reacted on the makers of the higher grades of steel, and they in turn strove to improve their product and succeeded in melting what were the first commercial alloy steels. The first of these, no doubt, was the tungsten steel of Mushet which, owing to the peculiar properties of this material, was named "self-hardening steel," inasmuch as it required no other quenching than cooling in air to obtain a hardness as a tool which up to this time had been unthought of.

Mushet also experimented with titanium. His expectations, however, were not fulfilled, and he turned his attention to the use of the elements of chromium and

manganese with tungsten. It is indeed unfortunate that Mushet did not pursue the heat treating of his steel with as much interest as he did the invention, as probably the production of high speed steel would have resulted years earlier.

Silicon and Manganese.

Knowledge of silicon and manganese as alloys was limited up to 1880, although Gautier in 1876 had made observations regarding the hardening properties of manganese. R. H. Hadfield in the year 1880 began probably the first thorough research in the metallurgy of steel regarding silicon and manganese. As a result of his investigations he published works of vital importance for the development of steel with these elements. Hadfield justly designates the year 1888 as the beginning of a thorough knowledge of alloy steels, when quite a number of such steels were produced in large tonnages and the use of silicon and manganese for the improvement of the physical and magnetic qualities was made practical.

Chromium Steel.

The founder of the chromium steel industry in America was Julius Baur of New York, who, after receiving letters patent for the manufacture of chrome steel, formed a company in 1869 which soon marketed its product with success. In Europe chrome steels were first produced by Holtzer and Company, Unieux, France. In 1870 they manufactured chrome steel armor piercing shells and armor plate containing about 2% chrome. Soon thereafter Hadfield began the manufacture of chrome steel in England, and in 1882 furnished chrome steel shells to the English Government which penetrated 8″ wrought iron plates.

The development from this time on was quite rapid and chrome steel was introduced largely for safe work, jail work and other lines somewhat related to its original uses.

The modern manufacture of this steel has broadened it beyond these uses and a large tonnage is now annually used by the ball and roller bearing industry. It is also used extensively in tool manufacturing lines and for other purposes where intense hardness is essential.

Nickel Steel.

From 1822 when Stodart and Faraday at Sheffield published their experiments on the alloying of nickel and iron, up to 1885, when a pure ferro-nickel was brought out, nickel steel, on account of its expense, was not developed to any great extent. While during this period Wolf, Fairbairn, Therber, Bessemer and others carried on extensive and valuable investigations, contributing to the development of this steel, it nevertheless remained for James Riley, then of Glasgow, to demonstrate by practical tests the advantages of alloying nickel with steel. Riley's paper on this subject, read before the Iron and Steel Institute of Great Britain in 1889, gave an impetus to the introduction of nickel steel in a commercial way.

The advantages of nickel steel in ordnance led to its use in the manufacture of guns of heavy caliber. The fact that the propeller shafts of the gigantic doublescrew express steamer Deutschland, launched in 1889, were made of nickel steel is evidence of the remarkable progress made in the manufacture of this steel and the recognized advantages in its use.

Nickel steel is now used extensively in automobile construction for parts such as frames, gears, shafts, and its utility in fields of structural fabrication, engine building, ship building, and many kindred lines too numerous to mention, is established and increasing.

Vanadium.

In 1803 Del Rio, professor of mineralogy in the City of Mexico, isolated this element and called it erythronium. However, it was not until 1830 that Sefstrom, a Swedish

investigator, succeeded in attributing the superior properties of some of their soft irons to this wonderful element, and gave it its present name.

The manner of the use of vanadium and its effect became known no sooner than 1900 through Arnold, who demonstrated a method of using it in a commercial way. Further investigations as to the action of vanadium in steel have been carried on by Nicolardot, Guillet, Putz, and others. With its marked affinity for numerous elements it was found in minute contents combined with the various minerals universally.

Owing to its enormous cost, which in 1895 exceeded \$10,000 per pound, very little was done with it as a steel alloy, but a vast deposit was unearthed in South America in 1905 and its cost was thus soon brought within reach of the commercial consumer.

Its property as a scavenger in cleansing steel of their impurities other than phosphorus and sulphur, and the dynamic qualities, together with the superior static results obtained when used in conjunction with chrome, created a demand for this alloy which has been remarkable. The Swedish irons used as a base for high grade crucible steels owe their virtues to this element. One of the first extensive uses synthetically, however, was in conjunction with high speed steels whose cutting properties were trebled and even quadrupled thereby.

The automobile, locomotive and high speed engines, with their demands for anti-fatigue material, opened a wide field for this product. It was this demand that caused the entry of the open hearth and electric furnaces into the manufacture of this alloy steel.

About 1907 chrome vanadium steel was first successfully made in the open hearth furnace in commercial quantities. The consumption of vanadium as an alloy has steadily grown so that today it is used in combination with practically all other alloys, and in crucible, electric and open hearth practice.

Recent Developments.

The use of alloys in the manufacture of steel was effected in a commercial way about 1880. The demands of a steel to meet the use of more powerful explosives was the first influence toward the use of alloys and resulted in the introduction of nickel and chromium in steel for ordnance work. In their infancy these steels were made and alloyed in the crucible, and it was from the crucible mills with their ultra-expensive practice that the consumer obtained his supply. Later the demand increased so tremendously that the open hearth and electric furnaces were drafted into service, the former turning out an excellent product at a very much decreased cost owing to the tonnage involved, and the latter rivaling the crucible for purity and with its costs also decreased as against the crucible practice. This was due to the charge of tons in the open hearth and electric as against the crucible's charge in pounds.

During the past decade wonderful strides have been made in the development of alloy steels of high physical properties. Such developments were brought about largely by the severe and exacting requirements of automobile manufacturers, as with the introduction of motor vehicles it became necessary to economize in space and weight, and to meet these requirements metallurgists turned their attention to the development of steels of greater efficiency. This resulted in the adoption of practically standard analyses, by which small percentages of the standard alloying elements, vanadium, chromium, nickel, tungsten, etc., introduced into the metal increased its strength, toughness, hardness and other physical properties sufficiently to meet the exacting conditions. In addition to the alloy steels containing the above mentioned elements, another class was developed by adding abnormal quantities of the essential impurities, silicon, manganese, or both, either with or without the aforesaid alloying elements. The production of satisfactory man-

ganese, silicon and silico-manganese steels is now commercial.

Machineability of Alloy Steels.

Some consumers specify alloy steels which must be made to analysis, heat-treated to certain required physical results, and then either cold drawn or turned and polished, so that the consumer has only to use the steel as furnished by the steel manufacturer in its finished form. This demands of the steel maker not only heat-treating facilities but equipment for producing steel with the highest possible finish. The problem which is now confronting the steel maker more and more is the machineability of steels capable of possessing high physical properties. Marvelous development in tool steels, due to the improvement of the present-day high-speed steels, has caused a proportionate increase in the efficiency of machine tools which means a "speeded up" production inconceivable ten years ago. I believe that the efficiency in improving machineable steels has not kept pace with the improvements in tool steels and machine tools. This is not entirely to be blamed upon the steel maker, as much steel is furnished in a green state, or the operations performed upon the steel before machining being thermal in nature destroy its production efficiency unless this structure is returned to its proper status. There is a large field for investigation as to the various mill operations to obtain a commercial practice which will deliver steel to the consumer in a uniformly machineable condition.

A few years ago, and even to date, a steel which was difficult to machine was "annealed." The peculiar characteristics of the steel were not investigated, but the steel was treated in a more or less superficial way and heated "somewhere in the neighborhood of 1500° Fahrenheit and cooled in a slow heat conducting medium," which sufficed to obtain more or less uncertain results for the customer. Inasmuch as we are living in a day of special steels and

each steel is indeed a deep study in itself, the problem of machineability becomes not that of a mere annealing (which in some cases is sufficient, however) but a scientific research of the metal through its many operations from ingot to bar. Casting, breaking down, rolling and principally finishing temperatures, all must be looked into with utmost care. These details must be not only ascertained but duplicated day in and day out in order to reach the ideal condition. Thus when each grade of steel is intentionally, and not more or less accidentally, made a consistent machining proposition, will the production which is sought be attained.

Specifications.

The question of chemical and physical specifications is an important one to the steel maker. It has been the habit of consumers when buying their materials to specify both chemical and physical properties, and in a good many instances properties that are conflicting and inconsistent. It has been our experience, and no doubt that of all the other makers of steel, to receive orders on which certain chemical limits that are commercially possible are outlined, and then physical results demanded that are absolutely impossible with the prescribed analysis. In some cases the ductility factors, viz., elongation and reduction, are specified at percentages that cannot be met with the high elastic limit required. In others the hardness (placed either at a maximum to obtain machining qualities, or at a minimum to assure the elastic limit being up to specifications) is entirely inconsistent with the tensile strength and elastic limit. These discrepancies are in a good measure due to the steel makers themselves because only a few years ago the data at hand on alloy steels was obtained through tests in which the type of steel was the only variable, little consideration being given to section when recommending a steel for a prescribed purpose.

A standard test piece which has been heat treated

after machining, as we all know, will show percentages of elongation and reduction which cannot be obtained with a test piece machined from a heat-treated part of greater section. Also a treatment which will produce certain properties upon a test piece treated after machining will not suffice for the heavier section. Because of the inconsistency of imposing physical specifications based on a standard test specimen heat treated, as against a specimen cut from a larger section after heat-treatment, steel manufacturers have often found difficulty in meeting the requirements demanded.

Physical specifications should be drawn up in accordance with the results which should be obtained from tests taken from the full section in question.

Data are often given out by steel manufacturers as to physical properties of steel without specifying the section from which the tests are made, which is thereby misleading.

Again, concerns have been impressed with the virtues of some type of alloy steel by reason of its exceptionally high physical properties, and assume, for instance, that a steel which is stated to show 200,000 pounds per square inch elastic limit must necessarily be better than one which shows only 150,000 pounds elastic, ignoring entirely the purpose for which the steel is to be used. In reality the lower elastic with greater ductility may, for a particular purpose, serve to better advantage than the higher elastic and lower ductility, both results, however, being obtained from the same steel by different thermal manipulation.

The various types of alloy steels each have distinct properties for a constant elastic limit. The elastic limit is the working feature in all parts because after determining the stresses and by adding a factor of safety there is obtained a gross stress which must be resisted, and this resistance must in all cases be exceeded by the elastic limit. The type of steel then to be selected should be determined by the nature of the stresses and not the

amount for it is possible to obtain equal elastic limits in several of the alloy steels that are made today; for instance, where an alternating stress will cause a chrome nickel steel to fail a chrome vanadium steel will serve satisfactorily, even though it is treated to show no greater strength. This is due to its superior dynamic properties.

The consumer should, when specifying steel, arrive at the grade through the nature of the stresses, the elastic limit by the amount of the same, and be content with the tensile, reduction, hardness, etc., which that particular type of steel must necessarily possess with a certain elastic limit.

Prospective.

The manufacture of alloy steel tube stock has received great impetus in this country since the war began. In fact, many consumers in this country have learned that a high grade product of alloy steels can be obtained from the American steel makers. Steels which were formerly purchased abroad are now being produced by American manufacturers with satisfactory results. Therefore, the American steel maker, as well as the maker of finished articles heretofore imported, can hope to retain this trade, it having been fully demonstrated that American steels are equal in quality to the foreign steels.

The railroads have been far less active in the adoption of alloy steels than the automobile manufacturers, though during the past few years there has been on their part a greater realization of the merits of alloy steels effecting greater safety when operating at high speeds.

The saving in weight in construction is a factor that the railroads cannot well overlook, as during the past few years the trend has been to tremendously increase the size of locomotives. This cannot be done without a decided increase in weight unless an alloy steel is used.

The first obstacle in securing a more universal acceptance of alloy steel by the railroads has been the lack of

preparedness on their part to properly heat treat. I wish to make myself clear on this point in particular, namely, that an alloy steel without heat-treatment is but little better than a carbon steel, and in some cases more dangerous. Sound business principles should prompt the user to heat-treat in order to obtain the maximum efficiency for which the consumer pays the additional cost for alloy above carbon steel. Proper heat-treatment will in many alloy steels approximately double the static strength and will at the same time produce a higher degree of ductility. Railroad shops as a rule are woefully lacking in proper equipment for heat-treatment, and until they provide furnaces of close and uniform operation and control, dependable heat measuring apparatus, suitable quenching facilities and mechanical methods of handling the material, it will be impossible for them to realize to the fullest extent the degree of superiority of the alloy steels over the carbon steels.

The steel maker can furnish the axles, side rods, and other forgings heat treated and rough turned, finished or ready for finishing, but he can only furnish such parts which are not in the course of manufacture subjected afterward to any hot work, and parts where no greater hardness than is consistent with good machining is essential.

A proper heat-treating equipment would be of great service to the railroads also in the rebuilding or repairing their present rolling stock with durable alloy steels.

I predict that the next few years will show a greatly increased demand for alloy steels from the manufacturers of railroad equipment, machine tools, engines, mining machinery, farm tractors, aeroplanes, etc.

Alloy steels will also occupy a larger field in marine construction, particularly in submarine work.

The aeroplane manufacturers are already calling for the highest grade of electric furnace alloy steels. If we review the wonderful development of aeroplanes in the

last few years we can readily get a better idea of the greater possibilities in the future.

The field for the development of the tractor engine offers one of the attractive American manufacturing possibilities. The successful development of tractor engines in a large measure will depend on the increased use of alloy steels so that the tractor may be lighter in weight and stronger in construction.

Many other manufacturers have up to this time overlooked the great possibilities in the use of alloy steels in their products. There is a wide field for development.

Conclusion.

The experience of alloy steel makers during the past seven years shows a steadily decreasing cost of production and a decreasing selling price due to many changes in manufacturing methods. Some mills which are now specializing in alloy steels have developed as the result of their experience methods of manufacture which are quite dissimilar in many phases to the manufacture of common steels. The waste product has been greatly reduced, this having been accomplished by the reclaiming of material which was formerly rejected. Heretofore, the practice was to discard a very large percentage of the heat which resulted in high cost of production. Economical methods put into effect resulted in a higher quality of steel and a better practice. While chipping, grinding and reclamation of steel in other ways entail a higher cost per ton for the making of the steel, they have resulted in ultimate decreased cost and cleaner billets, producing not only a greater yield of bars but a finished material free from defects and imperfections. This is beneficial not only to the consumer but also to the manufacturer who by conscientiously cleaning his stock is assured that the material will remain sold and give satisfaction.

Citing my company for example, rejections by the trade during the past seven years have declined very materially; that is, from 5 to 10 per cent. seven years

ago until during the past few years average rejections have been less than one-half of 1 per cent.

Lower costs are due also to decrease in cost of some of the alloys, as for instance ferro-vanadium, and to lower cost in heat-treating, because of the greater amount being treated together with improved design in furnaces to facilitate handling the stock. Lower selling prices will generally result in the further expansion of tonnage.

The perfection of the electric furnace for steel melting has enabled the manufacturer to duplicate by this method many steels which were formerly made in the crucible, and at a reduced cost. There is a large opportunity for introduction of such steels for use where the excessive cost of machining necessitates an absolute minimum of rejection, and which steels cannot be made successfully in the open hearth. This is especially applicable to parts where under rigid inspection minute defects cause rejections.

The advancement made in the manufacture of alloy steels in recent years is a tribute to the steel makers and speaks for the progress, the increased efficiency and years of hard work on the part of the steel manufacturer necessary to accomplish this result.

From one point of view this remarkable efficiency of practice is a greater achievement than some of the metallurgical successes in the field of alloy steels. It is a homely story of human effort which is only fully appreciated by the steel manufacturer.

President Gary: Discussion by Mr. George L. Norris, of the American Vanadium Company, Pittsburgh.

DEVELOPMENT OF ALLOY STEELS FOR COMMERCIAL PURPOSES

DISCUSSION BY GEORGE L. NORRIS

Metallurgical Engineer, American Vanadium Company, Pittsburgh, Pa.

I hadn't expected to be called upon to participate in this discussion and have not had the opportunity of seeing the paper before it was read.

I would call attention to the fact that this is just about the centennial of the investigations of Faraday on alloys of steel. Faraday's investigations covered a very wide range, including gold, platinum, iridium, nickel, copper and several other rare metals. All comparisons were made with Damascus steel blades. Up to very recent times the steel investigators seemed to be charmed with the wonderful results obtained by Damascus blades, and that steel was the criterion of all steels. They would say that a certain steel on polishing or etching gave a beautiful damascene, or that the steel gave a very good mirror polish. They were interested principally in steel for cutlery and for swords. The later developments in the alloys of steel have been largely along similar lines, that is, for warlike purposes and the development has been largely a struggle between attack and resistance of projectiles and armor.

The more recent development, of course, has been largely due to the automobile industry with its great demand for high grade steels. Mr. Rogers called attention to vanadium, which, while it was discovered about a hundred years ago, has only within the last fifteen or twenty years come into use as an alloy for steel. It has been demonstrated that this is the most powerful metal ever discovered for alloying with steel in small amounts.

In the case of Arnold's experiments referred to, the first tests were made with carbon tool steel. He found that with .20% to .30% vanadium he got about 50% increase in strength. Experiments with vanadium in combination with other alloys such as chrome, nickel, etc., gave very much higher physical properties, and the development of vanadium steels has been along the lines of these complex steels rather than with simple carbon-vanadium steel. The early price of vanadium was so high that the cost of simple carbon-vanadium steel was nearly as great as for the chrome-vanadium or nickel-vanadium steels with their much higher physical properties. A very great reduction in the price of vanadium in the last two or three years has again brought to attention the fact that vanadium added to straight carbon steel will give a very great increase in strength. This type of steel is now a commercial possibility and is one that will be very widely used. It is possible to use this type of vanadium steel without any heat treatment. There have been experiments under way in the last year with carbon-vanadium steel rails, and the comparison has been very favorable. The results show on curves twenty-five per cent. less wear in the case of vanadium rails as compared with rails containing fifteen to twenty points higher carbon on the same curve. A very noticeable thing in these rail tests has been that the low rail has shown absolutely no flow, whereas carbon rails in the same curve show fully a half an inch of flow.

In the case of locomotive forgings there is a very great field. The locomotive builders and the railroad motive power men have felt the need of a better quality of steel for such forgings as side rods, axles, etc. It has been tried to meet these requirements through heat treating the carbon steel forgings. This has not proved satisfactory in most cases. The increase in physical properties has been very small and the danger of failure due to improper heat treatment is very great. It is not possible to reduce the weights of the various locomotive parts to any great ex-

tent as in the case of automobiles. This makes the use of high-priced alloy steels almost prohibitive. Through the use of a carbon-vanadium steel it is possible to get physical properties by a simple annealing process equal to those obtained from heat treated carbon steel and at a relatively small increased cost. By this means, the uncertainty of heat treating large sections such as are common in locomotives today is avoided and the desired increase in strength is obtained. In other words, a greater factor of safety is obtained with a relatively small increase in cost.

The automobile field, of course, is one peculiar to itself; the sections are of relatively small size; in some cases the sizes used are so small as to seem almost unsafe; yet by the use of heat treated alloy steels with their tremendous strength there is perfect safety. The use of all alloy steels is developing at a very rapid rate. I know that the use of vanadium, with which I am more familiar, is increasing enormously and its use becoming common in all fields of the steel industry. (Applause.)

PRESIDENT GARY: Any further discussion? Announcements by the Secretary. (After these announcements.) We shall now take a recess until 6:30, when we shall assemble in the lobby adjoining, and at 7 we shall come to this room for dinner.

EVENING SESSION.

After the semi-annual dinner, which was served at 7.30 P. M., the meeting was called to order by the chairman, President Gary, at 9:15 P. M.

PRESIDENT GARY: We have a long program and a good one. The chairman will attempt to make it as short as possible; that is, by curtailing wherever it is possible to do so without interfering with the value and pleasure of the program. The room is crowded, as you see, almost as crowded as your mills are. It will be necessary to maintain the strictest order and give the closest attention, and for every one to do whatever is possible to aid in facilitating matters.

You will see by the program that the first thing is moving pictures, first by the American Steel and Wire Company, and then by the National Tube Company. We give them now the floor.

The American Steel and Wire Company pictures were presented by Dr. H. E. Horton, of Chicago.

DR. HORTON: The first reel this evening is an American Steel and Wire Company reel, beginning with the billet at the end of the re-heating furnace, and following the process of rolling rods and drawing wire and finishing with three of the big products, namely, wire nails, barbed wire and woven wire fences.

We are led to believe that iron and steel was the lever to lift men up out of barbarism to their present condition. If that is so, then wire of all kinds is the means of bringing this civilization to all peoples. For, from the wire adornments of the reigning queen of early times down to the humblest home in this country, where the wire is bought to tie up the stove-pipe, wire is in universal use.

The first mention made of wire is a difficult one to understand. We pass this over and come down and find

wire used in the ornamentation of the mummy-cases in Egypt. In a book called the Urkunden Buch, of Augsberg, there is a census of the people of the city, divided according to the business in which they are engaged, and in the year 1351, for the first time we find the distinction made of "wire drawers" and "wire millers." The wire miller was a man who took a rectangular piece and rounded the edge by hammering. Finally some one in this year 1351 discovered the use of the wire die and became known as "wire drawer." In 1400 Rudolf of Nürmberg, so often mentioned in this connection, made a great deal of this method of producing wire.

Now, to pass quickly on to a very interesting point in connection with the history of wire: In the early part of the eighteenth century the wire industry, the intense wire industry of the world, was in the Rhine Valley in Germany. Three towns, Altena, Iserlohn and Lüdenscheid, were towns of importance. One town drew coarse wire, another fine wire, and the third, the town of Altena, drew the medium-sized wire. Now to the point of interest. These men discovered that in order to carry on business to the best advantage, it was necessary to pool their interests; and so at that time, in the Rhine Valley, we have the first pooling association, or trust. All were included in this association; the small men, who drew wire in the farmhouse (for wire drawing at this time was a domestic industry) as well as the men who drew wire in the mill run by a water wheel. The production of poor product was prevented.

All the wire drawn was put into a bonded warehouse. Certificates or warrants were issued against the wire stored in these houses. Men of probity had charge of the warehouses and made the sales. Merchants bought the wire on four months' credit. The manufacturer, the small farmer, all who put wire into the pool, received from six to eight per cent.; a like amount was given to the pool. At the end of the year, coming together in a general meeting, the books were balanced and a dividend was declared

and distributed, covering the earnings of the period. This plan of manufacture and sale proved a great benefit to the small producer.

A man was not permitted to be a wire drawer save through his connection with a guild. It was impossible for a man to hand down this privilege to any other, save a favored son. A man engaged in the industry at this time, and they were turbulent times, was exempted from military duty; they didn't want to have him lost to them. That is an interesting point.

You all know the balance of the story of wire up to date.

This evening we are to have a moving picture reel picturing how wire is made to-day.

(Slide exhibited showing making of rods.)

When the rods have been cleaned, the next step is to prepare the lubricating coating so that the rod may be reduced in this conical-shaped hole in the hard piece of metal. First put on a coating of basic ferrous-sulphate, to prevent so called "cutting out," and on top of this a coating of lime.

When the rods are being pickled in the dilute warm sulphuric acid in the tub, they absorb hydrogen. While this is not a good thing for low carbon steels, it is very injurious for high carbon steels.

At the same time the lime coat is baked on by placing the rods in bakers the hydrogen is driven off. (View shown.)

The first nails were made in Paris in 1801, but the wire nail came into common use in this country in the year 1885, this being made possible by the labor troubles of the year.

Question: Which plant is this?

Dr. Horton: No particular plant. A number of plants were chosen in making the pictures, for it was necessary to find those plants that were best illuminated, in order to make the photographs, so you see one scene from one plant and one from another.

The invention of barbed wire was a great thing for the world, and much was expected of it. At that time the sheep-growing industry was a large one, and it was expected that the common curse of this industry, namely, the mongrel cur, would be held in bounds; but this was a false hope, and it was not until the present woven wire fence came into use on the farm, supplemented with the barbed wire fence, that it became possible once more to go into the sheep industry.

(New view.) This is one end of the annealing furnace, in which the annealing is done by passing the wire through molten lead.

(New view.) Moving through this vat, the wire is cleaned, and then passes into the galvanizing kettle, where it receives a coat of galvanizing, and as it comes from the end of the kettle it has more zinc on the bottom and sides than on the top, and it is wiped to insure a uniform coating.

(New view.) This is another end of the galvanizing kettle.

(New view.) This is the head or wiping end, where the uniform coating is made.

(New view.) This is one of the old fence fabrics, but it is shown for the reason that the work of the loom closely resembles that of a loom weaving cloth. (Applause.)

(New view.) There are two general types of woven wire fencing, the one called the "square mesh," and the one called the "triangular mesh."

(New view.) The next two machines shown are making the quadrangular mesh. This is the end of the reel, gentlemen. (Applause.)

Mr. F. N. Speller, metallurgical engineer of the National Tube Company, Pittsburgh, then presented moving pictures illustrating methods of manufacturing tubes and pipes, and some of the company's welfare work.

Mr. Speller: Mr. Chairman and members: I am asked to give you a word of explanation as to the pictures which will follow. This series of pictures, showing the

manufacture of steel tubes and pipes, were made to aid in the campaign of publicity and education which was inaugurated by the National Tube Company two or three years ago. The whole series includes the principal operations from the mines through to the blast furnaces, steel works, the various rolling mills, and shows the manufacture of lap-weld pipe, butt-weld pipe, and seamless tubing. Owing to the limitations of time, it will be necessary to cut down the series of pictures to one reel, the one showing the manufacture of lap-weld pipe. These pictures have excited the greatest interest among the users of tubes and pipe. Although the tube and pipe industry now ranks as one of the largest departments of the iron and steel industry, the making of steel tubular goods is a closed book to most of those who use these products. One object of these pictures was to bring the consumer into closer touch with the manufacturer and to remove the tendency to prejudice and misunderstanding which has existed in the past in regard to steel tubular products.

(New view shown.) You will understand that the steel is first rolled in the form of plate termed skelp. These pictures start with the charging of the skelp or sheared plate into a heating furnace preparatory to rolling it into the form of pipe.

(New view.) This shows the type of rolling mill used to bend the plate. You will notice that the edges are roughly lapped over. The skelp is then charged into a welding furnace of the regenerative type, with the lapped edges on top.

(New view.) This shows the mandril on which the pipe is welded. You will see the mandril is placed in between two rolls, being held there loosely on the end of a steel bar.

(New view.) Here we have the pipe passing out of the welding furnace over the mandril.

(New view.) The pipe is then passed through another set of rolls to give it the correct outside diameter.

This represents the operation. This particular pipe is twenty inches in diameter. Most of this pipe is made in twenty-foot lengths, but we have some mills that make this sized pipe in forty-foot lengths.

(New view.) This is the type of roll used to straighten pipe.

(New view.) After being straightened, the pipe is passed on to a cooling table, on which the pipe is kept revolving until cold.

(New view.) When finished, the rough ends of the pipe are cut off in this fashion with a cold saw. Each crop end is used as a test piece.

(New view.) The object of this flattening test, as you see, is to develop any weakness in the weld or the material.

(New view.) The end of the pipe is then rounded up and reamed.

(New view.) The threads are carefully gauged.

(New view.) This shows the hydraulic test. Every piece of "National" pipe is subjected to an internal pressure of 600 pounds or more, according to size; every piece of our pipe from one-eighth of an inch up to thirty inches in diameter is tested in this way.

(New view.) The system of marking the name "National" in raised letters was started a couple of years ago, at which time the weights were standardized. This work is therefore a guarantee that the pipe is up to standard weight. (Applause.)

(New view.) This shows testing of lap-weld locomotive tubes. These tubes are the highest type of welded tube made. The ends are cut as you see as in the case of the large pipe, and are rigorously tested. Each end of every tube is put through that test, which is a combination of flange, flattening, and crushing down test.

(New view.) Here is the hydraulic test again. These are standard specification tests required by the railroads for locomotive tubes.

(New view.) This piece of casing was crushed in by

a dynamite explosion from about twenty feet long down to a length of six feet, without fracture at the weld or in the steel. (Applause.)

(New view.) This is a view showing the ore docks and unloading plant at Lorain. (Applause.) We are showing you two panoramic views here, typical of modern mills designed exclusively for the manufacture of steel pipe. They include a complete layout from the blast furnaces through every department to the finishing mill. This plant at Lorain is a little over two miles in length and contains a complete system of good roads for the use of trucks. These roads have been made from blast furnace slag and have resulted in the use of that slag throughout the adjoining counties for the same purpose.

(New view.) This shows the Bessemer department.

(New view.) Here is the gravity distributing yard. These cars are weighed at the rate of ten a minute and distributed without riders.

(New view.) The automatic weighing scale house.

(New view.) Type of engine used to haul the ore cars.

The last scene will show a panoramic view of the National Tube Company's plant at McKeesport. This plant occupies a rather congested piece of land on the river, and although about the same capacity as the Lorain plant, the mills are much more crowded together. The view starts with the blast furnaces and works up the river; here are the skelp mills; and finally the tube and pipe department,—a building which covers about twenty-three acres.

(New view.) This is a useful suggestion from our distributors. A word to the wise: "Specify 'NATIONAL.'" (Applause.)

The next reel, gentlemen, has to do with the welfare work. Mr. Close, if he had been here, could have explained this much better than I can, but we are all very much interested in this work.

(View shown.) These are views of the Shelby Steel Tube Company at Ellwood City, Pa.

(New view.) Garden plots. Since this picture was taken the garden plots have been increased to 110, and the value of the product from these plots this year is estimated at $10,000. The company provides the land, ploughs it and fertilizes it. The men and their families do the work. The size of each plot is 50 by 175 feet. About 1,500 men are employed at this plant.

(New view.) Employees at work in their gardens.

(New view.) This playground has an average attendance of 200 a day. The company installed the grounds and the apparatus and pay the supervisor. (Applause.)

These are an interesting series of views showing the children in the swimming pool, playing hand-ball and other games, view of drinking fountain, view of basket weaving, volley-ball after lunch, at the noon hour; Saturday afternoon on the golf links.

(New view.) These pictures were taken near the plant of the National Tube Company, McKeesport. This is a much more congested district, and surroundings not quite so pleasant as those you have just seen. The company co-operated with the city in laying out this piece of land as a playground, to keep the children off the street. The railway cars are on one side, and the street cars on the other. The average attendance at this playground runs 350 a day. It might interest you to know that the majority of these children range between six and twelve years of age, although twenty per cent. of them are four years and under. The main object, of course, is to benefit the children, but incidentally it helps in the welfare of the home by allowing the women to go about their work without anxiety or interference.

(New view.) Sewing class.

(New view.) McKeesport municipal swimming pool. This pool was put in by the city of McKeesport and shower baths, dressing rooms and apparatus by the National Tube Company. The company also laid out and

equipped athletic apparatus on the adjoining field. This pool is approximately 200 feet square, the largest of its kind in a city of this class. The water is chemically treated and filtered, and a continuous fresh supply kept flowing in. The whole tank is emptied and renewed once or twice a week. The water is from two to eight feet deep. The attendance here some days has run as high as 5,000. When you understand that the river water here frequently carries 25 grains to the gallon of sulphuric acid you can appreciate the privilege of neutral water to swim in.

(New view.) This is the municipal water works filter plant from which this water is supplied.

(Other views of swimming pool in use.) In the winter season this pool is allowed to freeze and used as a skating rink.

(Very interesting swimming and diving scenes.) (Applause.)

President Gary: Some of the speakers on our program for to-night are accustomed to speaking, I suppose, others are not. The latter may be more or less embarrassed. I want to say for their comfort that most of those who have had experience in speaking on public occasions have just about the same feeling, no matter how much practice they have had.

It may be interesting to you to tell you that on a certain occasion, in New York, when a banquet was given to one of the members of the Institute, many of those who are here were present on that occasion. During the short time before the close of the exercises, the audience insisted upon Mr. J. P. Morgan saying something. He hesitated and then declined, but finally was persuaded to rise. He said a few words. His remarks were eloquent and impressive, as every one of those who listened will testify. They will never forget the occasion. Mr. Morgan, as he stood there, placed one of his hands on the shoulder of the gentleman next to him and the other on the table; and he told me afterwards that, except for that support on either side, he would not have been able to

stand, so embarrassed was he, so weak was he. So if there are any here who are not accustomed to speaking and when called upon tonight have any of that feeling, they may be satisfied that they are not the only ones.

Another thing I want to say for their comfort is that it is not only the speaker who is embarrassed that suffers or feels he is not doing as well as he ought to. I have heard older ones state a great many times after our meetings when young men have been called upon to speak, that it was wonderful how well the young men spoke. You are doing very much better than you realize. And then another thing, you will all go home, thinking to yourselves as you are going, of a great many things that you ought to have said that would have been very much better than anything you did say. All speakers are exactly alike in this respect. Even Jim Hoyt, with all his eloquence, every time he goes home after a speech, thinks of some of the fine things he ought to have said. (Laughter.)

Now, there is just one other thing. It has been complained that in some of our large meetings many failed to hear what was said by some of the speakers, because their backs happened to be turned as they were speaking from some part of the hall; and it has been suggested that if, when a speaker is called upon, he would come forward to some place upon or near this platform, it would be very much more agreeable to the listeners. It will be necessary, of course, to maintain the strictest order if we wish to hear what is said. And because of the length of the program, it will be necessary to limit the time of the speakers.

I suppose that after this list which has been provided is finished, the audience will, as usual, call upon Mr. King and Mr. Hoyt and others, for a few remarks. If these gentlemen speak too long in the opinion of the chairman the gavel will come down, because we want to finish this program.

The first on the impromptu list is Mr. Ralph H. Sweetser, president of the Thomas Iron Company, Easton, Pennsylvania. (Applause.)

(Mr. Sweetser was seated at the side of the room opposite to Judge Gary.)

Mr. Sweetser: Mr. Chairman, it looks so far from here over there that I beg leave to stand here, and if I am not heard will some one please tell me so. (Getting up on his chair.) I am so short that I am going to get on this chair, so that I may be seen if not heard.

My surprise at being called on for an impromptu speech was all over about a month ago. (Laughter.) But my surprise was just as great and just as genuine as the surprise of Mr. Butler when he is called on for an impromptu speech. I didn't know what I would speak about, but after I heard the talk of Mr. Jones this afternoon on the "Under-Advertising of the Iron and Steel Industry," and after I had heard Mr. Rogers speak about the vanadium worth $10,000 a pound that was put into alloy steel, I thought I had something to say about the advertising of something so common and so crude as pig iron.

I have been a sort of a joke among my friends in the iron business for the last year because I supposed a while ago that pig iron could be advertised and made interesting. In a certain brand of pig iron in the Lehigh Valley, we have found some vanadium, and we have advertised the fact, and some of the results have been remarkable. One of the results was that we have got a little higher price for our pig iron. (Laughter and applause.)

Now, in advertising that pig iron, the thought first came in this way. In the Lehigh Valley district there are many users of pig iron. Riding in a street car one day and reading the car signs, I thought, "Why shouldn't we have a sign up there saying that we made pig iron here in the Lehigh Valley and that people should use home pig iron?" I put that up to an advertising manager, a friend of mine, and he said, "Don't do it, you are not reaching the right people." I said, "What shall I do?" He said, "Go to an advertising expert." I did so, and sent for some of the experts of the trade journals. They

said, "Start at the top end, and tell what you have got, and tell the truth." That is what I tried to do. In that talk of Mr. Jones he said that you should tell the truth about your articles and try to tell only one thing at a time. Now, we had so many things to tell about our pig iron that it lasted a year and a half. And the result has been, as I said, in the first place commercially correct because we got more money. In the second place, it has brought attention to something that has been interesting not only to the users of pig iron but also to other people.

I had the pleasure last Wednesday of being present at the inaugural of Dr. McCracken at Lafayette College, and I had the pleasure of seeing our beloved president get there his degree of Doctor of Laws. (Applause.) In that college on the hill at Easton, they have been experimenting with vanadium pig iron and they were so much interested that they have even started another series of tests in the vanadium alloys.

Now, that shows you how a thing that is perhaps commonplace can be made interesting. The work of that department has proved so interesting that they are planning to work throughout this year on something that was just started as an advertising scheme. Some people say, "Now, Sweetser, that is all bunco business about the vanadium in your pig iron." Well, I answer that that is not so, because they have proved it. (Laughter and applause.) I picked up a Philadelphia paper the other morning, and here is what I read—

QUESTION: What did it cost you? (Laughter.)

MR. SWEETSER: "Mr. Schwab gets Thomas Iron Company. The significance of the Thomas Iron Company as a valuable asset will be shown in the construction of submarines with vanadium pig iron." Now, we guarantee that our pig iron will sink just as fast as any other pig iron. (Laughter and applause.) But I did want to say, in connection with Mr. Jones' address this afternoon, that if you have anything to advertise, even though it may seem commonplace to you, tell the facts about it

and you will find that other people will be doing the thinking as to what they can do with that product. The advertising of pig iron has become interesting; it has become remunerative; and I think it is going to stir up a lot of interest in something that has not been considered as interesting as steel, for instance; but I believe, as they say in that play that was in New York last year, "It Pays to Advertise." (Vigorous applause.)

President Gary: We would be glad to hear from Mr. Daniel B. Meacham, of Rogers, Brown & Company, Cincinnati. (Applause.)

Mr. Daniel B. Meacham: Mr. Chairman and fellow members: I think that this meeting and the preceding meetings have proven conclusively that those who organized this Institute were men of broad vision and high ideals. We all know the many benefits that we have derived from this Institute and it is not necessary to try to enumerate them. We know that the mere coming together and the cultivation of a friendly spirit is one of those benefits; and while the business rivalry may be as sharp and keen as ever before, yet it is carried on in a very different way, I think, from what it was in years gone by. But if we were to ask these organizers to-night from what source they are deriving the most satisfaction in connection with this Institute, I thing they would tell us that it is not in the profit that they may have made from it, but in the feeling that in the welfare work promoted by it they are doing good to their employees and their employees' families. I believe that when the busy man has a quiet time and is thinking over the things that are worth while, it is the comfort, the pleasure that he has given to others, rather than anything that may have accrued to himself, that is a source of abiding joy to him.

It was my privilege last month, at Atlantic City, to attend a conference lasting four days, of the International State Committee of the Young Men's Christian Association and their secretaries. There were about 180 present, and looking over the list of membership I saw the names

of Cyrus H. McCormick, George W. Perkins, and James Bowron, who are also members of this Institute. The secretaries came back from all parts of the world, and gave accounts of the wonderful work they had done and of the taking hold of American ideas; some gave reports of the work they were doing in the war camps in England, France, Germany and Russia.

But I was especially interested in the department of industrial work in this country done by the Association's trained men, who came bringing reports from the logging camps of the South, the logging camps of the North, from the coal mining, the iron mining, the copper mining districts, from the great industries of iron and steel throughout the United States, where they are carrying on an efficient welfare work. It occurred to me that while many of us perhaps had been importuned by stockholders during the last few years to organize a welfare department for their benefit, the time was coming when they might be cared for and there might be something left over to do a greater welfare work than ever has been attempted before.

I saw figures of what some corporations and individuals are doing. They have invested about $1,750,000 in these Association buildings and plants and equipments and are contributing about $175,000 yearly to carry on the work. Some of them, in the logging camps, are very rude structures, and others are like that magnificent one at Gary, Indiana, which I think our worthy chairman knows about. Any of those in this Institute who haven't had the time or the opportunity to work their plans out on the lines they wish, will find in this Association a lot of specialized men whose business is welfare work and who, if requested, will cheerfully give their time and their services to do anything on broad, humanitarian lines for the benefit of all of us. We understand the prejudice that some employees have against anything that is done for them by their employers; but these same employees will take hold eagerly of those things toward which they

can contribute of their own time and their own effort and where they can have a place in the committee of management and do something for themselves. Why may we not make larger use of the facilities of this great Young Men's Christian Association? (Applause.)

President Gary: Mr. William S. Horner, of Pittsburgh, Vice-President of the American Rolling Mill Company, will now address us.

Mr. W. S. Horner: Mr. Chairman and gentlemen: During recent meetings of the Institute I have been much interested in all of the papers which we have heard, not that I could understand them all, for I could not; there were very few of them that I could understand, because I am not a technical or metallurgical man. Nevertheless, I learn something from hearing these papers. I have observed that most of the papers have been from the operating departments of the various concerns. I think that now nearly all of the departments of the various divisions in operating have been well heard from. The papers represent most careful study and give to us the result of painstaking effort, with a view to reducing cost and giving the public a better product. We have also on several occasions heard from other departments—auditing departments, purchasing departments, etc., all the way through. I cannot recall that there have been any papers from the sales departments.

I am connected with the sales department myself, so what I say will be a reflection on myself as well as on you of the sales departments of other companies. I have wondered why it was that we had no papers from the sales departments, and have about come to the conclusion that it was not the wish of the committee to demoralize the other departments by hearing from them. (Laughter.) I have a conviction that the weakest department in the whole business is the sales department. (Applause.) If the other departments had been guilty of the same serious stupidity that the sales departments have been guilty of, we would all have been in bankruptcy long ago.

We are not making sales today. We are making contracts; and be it known that a contract is not a sale. And when you consider the effort that has been made—I have referred to the matter of reducing cost and giving us the benefit of the best thought of these men of the operating departments, but there is very little of that that reaches the stockholders, by reason of the blunders of the sales department—you will realize what I mean when I say that the sales department is the weakest of the lot. We make contracts covering delivery over a period of six months, and then after the contract is made we try to make a sale of the first month's quota. If we can get the buyer to take it and can believe what he says, we give him the product for the first month at his price; so that during the period of six months we will probably have made six efforts to get delivered the materials which were contracted for. In this manner we are making contracts and call ourselves salesmen. (Applause.)

I think it is true that during the last depression—we are just emerging from it now, and are emerging from it largely because of extraordinary conditions which exist abroad in the furnishing of war materials, etc.—the prices of finished steel products reached about the lowest point they had ever gone, perhaps the lowest. They would not have gone so low, I feel, possibly you feel, if contracts had been mutually binding, and if the buyers had had some interest in the maintenance of staple market conditions, which they did not have. Very soon, we cannot tell, it may be when this war is over, we will enter another period of depression, keen business depression, and if, before that time, we can have introduced into the sales departments of our various companies some fundamental common sense with regard to contracts and the mutual obligations which should go with them, we may be able to tide over or to bridge over that period and thus prevent the extreme depressions which we so often have in our business. I like the motto of the Institute; nothing could be better, "Right makes Might." But I submit for your

consideration, that until we introduce into the sales departments of our various companies sensible and right methods and principles, we can not expect to make this motto live in our business as it is our right to expect it should. (Applause.)

President Gary: We shall have the pleasure of listening to Mr. Julian Kennedy, of Pittsburgh. (Applause.)

Mr. Julian Kennedy: Mr. Chairman and gentlemen of the Institute: Some years ago a resident of Pittsburgh went abroad and registered in a hotel in one of the capitals of Europe, as from Pittsburgh. The clerk said to him, "That is near Homestead, isn't it?" (Laughter.)

The Pittsburgh people always like to come to Cleveland, not only because it is a great manufacturing city, as explained by Mr. Mather this morning, but because it is a city of great ideals, of great civic pride, of high moral ideas, of progress. Mr. Mather very modestly didn't tell us how much he has to do with these things, but I will tell you it is not a little. (Applause.)

Cleveland is a city which years ago placed in its office of chief executive one of our well known iron and steel men, and a man also of high ideals, whom many of us did not appreciate at his true worth until we saw 100,000 of the poor citizens of Cleveland waiting in the rain as his remains passed through the streets on the way to his funeral, a man who has left his impress on the whole United States and on the whole world, a man whose name will grow as the years go by—Tom Johnson. (Applause.) And Cleveland is a city which now honors itself by having as its chief executive a man of worthy ideals, and a man from Pittsburgh, can certainly appreciate a mayor of that kind. (Laughter and applause.)

A good many years ago a very brilliant iron and steel man from Pittsburgh told me, as one of the fundamental principles of business, that next to making money yourself, the best thing to do was to make your competitor lose money. Now, it is a far cry from that to the papers that we heard today—young men of large companies

giving the result of hard, earnest, diligent toil, to all their competitors. It is on a different scale altogether. And that change in the general spirit of things is due largely to this society, and still more largely to the president of this society. (Applause.)

And right here, in passing, I want to say that Lafayette is not the only university that has honored itself by giving a doctorate to our worthy president; the University of Pittsburgh recently did the same thing. (Applause.)

I am glad to come to these meetings, glad to hear the fine papers we have, and the always thoughtful addresses of our president. I was very much impressed with his address today, and I would like to paraphrase a little further one quotation which he made, and that is that nations do not live to themselves alone. It is up to us to remember, while we are very cheerful here today because we are making money and the steel business is flourishing, to remember the old lady who said that her boys were not suffering from hard times, because every Sunday they made six dollars off of each other playing poker. (Laughter and applause.) Now, while we feel that this is a flourishing year, don't let us forget that to a certain extent this flourishing of business is due to the misery of our brethren across the seas. And while business is stimulated by the war in Europe, I don't believe there is a gentleman here who would not cause the war to stop this minute if he could, regardless of any possible profits on the business in which he is interested. (Vigorous applause.) Our president said today, very truthfully, that if the inhabitants of Europe knew the true inwardness of the war, the plans of the kings and rulers that were bringing it about, it would come to an end. If the people of Europe knew, as we do, that undue armament always brings war and always will bring war, they would not have had a war. The people of Europe didn't know that, but we know it; and it behooves the engineering fraternity in general not only to observe the

proper amount of publicity in their doings with the public, but it is part of their duty to guide the opinions of the public, which is made up of, we love to think, intelligent people. We know some of these things that many of the people of Europe do not. Let us not allow the people of this country to be stampeded into undue armaments or preparation for war, which, as sure as the sun shines, will bring us to war. (Applause.)

PRESIDENT GARY: Colonel Henry P. Bope, First Vice-President of the Carnegie Steel Company, Pittsburgh, will now address us. (Applause.)

COLONEL BOPE: Mr. President and associates: The statements just made by my friend from Middletown (Mr. Horner) have almost made me forget the extemporaneous speech I was told to prepare. The only explanation I can make for what I regard as an extraordinary position to take is that it must be based upon personal experience. In my own work, covering thirty-five years in the line of salesmanship, I have never found anything to justify the statements that he has made tonight.

But, Mr. Chairman, this is supposed to be an occasion for good feeling, good comradeship and good fellowship, and I don't want to sound a single note of discord.

The pictures thrown upon the screen to-night, which we have just seen, bring in such a personal interest in humanity that it makes one feel that language is superfluous. Yet beyond anything that has been said to-day, able and deep as have been the papers and their discussion, there is one thought more than any other which is dominant to-night, and that is that humanity has had a distinctly less value during the past year than it has possessed in many years before. This is entirely due to the conditions prevailing abroad where the highest types of manhood have been simply food for powder. It has created a disregard for those ideals which we have heretofore possessed—the ideals that have been taught us by

poets and preachers through all the ages—the ideal presented by Tennyson when he wrote in "Locksley Hall,"

> Men, my brothers, men, the workers
> Ever reaping something new,
> The things they have done but an earnest
> Of the things they shall do.

And so in a brief consideration of this subject on my part to-night it is to put humanity on the plane where it ought to be.

I am induced to make these remarks by a statement made night before last in the City of New York, by Major General John F. O'Ryan, the head of the New York National Guard. In view of that statement I am almost tempted to indorse the words of Mr. Kennedy, although I am heartily in favor of the proper preparedness for defense in these United States. General O'Ryan said that the only way to make a soldier is to absolutely drive every bit of initiative out of the man, pound every bit of individuality out of him, making him a cog in the machine only, and that the officer who stands behind him should keep the revolver upon his knee ready to enforce discipline.

I can't indorse such an idea even as an officer of the National Guard, which I am. I do not believe in a method of that kind. I believe in recognizing the humanity and the individuality of men, and I can't think that the English "Tommy" or the French "Jacques" to-day, in view of their brilliant work and splendid soldiering, require any such discipline as General O'Ryan would like to use among the young men of America. If we are to have an army let us have the American initiative, the American individuality. We want the same type of men as went out in 1861,—the best blood and brain of the Nation. We want men of whom the Psalmist said, "They were created but little lower than the Angels," and whom Shakespeare, through the mouth of the moody Dane, described in those wonderful words:

What a piece of work is a man! How noble in reason!
How infinite in faculty! In action how like an angel!
In apprehension how like a god!

That is my ideal of American manhood. So the thought that I would like to leave with you to-night is that we do not want any lessening of this ideal. And in any consideration of such a value it is not necessary to consider what that great organism we know as the German army produces in the way of a well-regulated machine. After all, the highest type of a soldier, as the highest type of a man, is the one who performs his duty from a sense of duty and from the obedience that comes from his knowledge that it is what he ought to do, not merely what he must do. It is the same ideal as was expressed by Antony over the body of Brutus:

"This was the noblest Roman of them all.
His life was gentle, and the elements
So mix'd in him, that Nature might stand up
And say to all the world, 'That was a man!'"

Lastly I should ask that we as manufacturers do not so far carry the idea of organization as to produce a mere classification among our employees; with the result that no matter what may be the talents, the genius, the capacity and the experience of men, so long as they are in a particular class they can get no farther. The time has not yet come in this great republic of ours, so full of opportunity, for anyone to set up a dividing line and say, "Thus far and no farther." (Applause.)

These Institute meetings of ours are wonderful opportunities. They promote a real and a broad humanity. They have encouraged social comradeship, they have created ties among us which have made the doing of business easier. They have made everyone of us a little bit wider in judgment,—a little bit higher in our ideals, and as we go on learning to appreciate each other better, as we are doing, we can readily see how wonderfully im-

proved will be our methods and how much greater will be our successes. (Applause.)

PRESIDENT GARY: Under the circumstances, I think I am justified in saying, with reference to this question of armament, that perhaps there is no real difference between the two speakers who have so eloquently referred to this subject. All of us love peace and hate war. We would be glad if all the nations could be disarmed and were disarmed because unnecessary to be armed. Some believe that if there were no armaments there would be no war. Others believe it is largely a necessity on the part of any single government to be prepared to protect itself. But, after all, it is a question of opinion as to what is necessary and what is not necessary.

The next speaker is eminently successful in his own business, but never to the prejudice of a competitor or of another. His belief and his ideal is that we help ourselves best when we help others. He is the advance agent of good will, of good treatment of others, and of prosperity generally. I introduce Mr. Clarence H. Howard, President of the Commonwealth Steel Company, St. Louis.

MR. HOWARD: Mr. Chairman and fellow members: It is a great pleasure to be here to-night, but I find myself a good deal like the young man who asked the old gentleman for the hand of his daughter. He said the young man hadn't made his way and therefore he couldn't let him have his daughter. Thus spurred to effort the young man said, "I will make my way," and he started West to build himself up. He did build himself up, and then he wrote a long letter to his sweetheart, telling her what he had accomplished. Like all lovers, towards the end of the letter he became poetic and said, "I builded better than I knew." She said, "That will get dad, sure." But the old gentleman was a little hard of hearing. When she read the letter to him and looked up for an answer, the old man said, "That is just what I thought about that kid, he bit off more than he could chew." (Laughter.) Now, I am

not altogether sure that that is not what I have done tonight in accepting this invitation.

My subject is Fellowship, the basis of safety first, of effective team work, of success. Only a small part of safety can be had by mechanically safeguarding machinery, but most must come through true Fellowship.

We all know that the acme of workmanship is willing, skillful workmen. Skill is doing the right thing the first time. A willing man not skilled, or a skillful man not willing, will not get results. Skill and Will must be combined through Fellowship.

We have chosen the name Fellowship in contradistinction to Welfare, because Fellowship puts all on the same plane, from office boy to president, to work problems out together and thus avoid any sense of paternalism.

Under our Fellowship Department we have club house, lunch rooms, steel lockers, commissary, dispensary, safety first activities, refrigeration plant with a sanitary fountain every 50 feet through the plant, and other things of similar nature. Last but not least is our school where we endeavor to inspire each one to develop his capabilities to the utmost. Thus he becomes helpful to others and enjoys the reward of accomplishment—which again spells Fellowship.

Our worthy chairman, Judge Gary, has, through his example, shown that true co-operation, not competition, is the life of trade and the security to commercial activities and the safeguarding of our American institutions. He knows that "the right way gives us the right of way." We all, I think, are coming to know we are selling service—not merely materials—and service must be expressed in safety, efficiency and economy. Then the question is not *first cost,* but to give and get the greatest amount of service for each dollar expended. Our chairman has shown us that it is not what we say, but what we practice and understand of what we say, that counts.

Fellowship is a comprehensive vital force, always

finding expression in the Golden Rule. It broadens our views, increases our abilities, enriches and purifies our character. Fellowship is the basis of all "Safety First" activities, and without Fellowship there can be no real and lasting success in any undertaking. It establishes a higher civilization and progress. Its very nature makes it unselfish, therefore it cannot exist alone but requires all mankind to share it. One of its chief foundation stones is co-operation.

Fellowship steadies our boat, calms the storm, enriches our lives, and produces most effective team work. Fellowship never fails, nor is it ever expressed in vain, though it does not always meet with an immediate response. In families Fellowship establishes a practical co-operation in working out the problems of the day. Therefore, the home becomes an important factor and aid in establishing universal Fellowship.

So, you can see, Fellowship will aid in ending strife, worry, strikes, and not only end wars but eliminate their possibility, for in Fellowship there can be no elements of prejudice, hate, envy, malice, greed or "who shall be greatest."

Think of the progress in the steel world.

Progress is the shortest distance between two points, from the thing desired to the thing accomplished, illustrated by the main line of a railroad, with success of accomplishment as our destination. We start down the main line and soon encounter a switch or temptation called Prejudice (the greatest foe to Progress), which, if indulged in, automatically opens and lets us on side track, which is rough and leads to nowhere and we are compelled to return to same switch in order to again start on line of progress; thus losing much time. So, we find this main line of Progress lined with temptation switches, such as dishonesty, anger, hate, envy, drinking, gambling, and "who shall be greatest," etc. The man, company, state or nation that avoids these temptation switches will arrive at destination, Worthy Achievement, much more quickly and surely. (Applause.)

I would like to clinch what I have said with the following story:

A lady went to Heaven, and when she arrived she was questioned as to whether she had been good and read her Bible, and what part of it she liked best; and she said that the thing in the Bible that interested her most was where it spoke of the mansions that were built by the Heavenly Father for His children. "Well, then," asked the guide, "you are looking for your mansion?" "Yes." She was taken down the line and saw a most beautiful mansion. She said, "Oh, that must be mine." "No, that is not yours." Finally they came to a little log cabin and her guide said, "This is your mansion." She became very much disturbed, and said, "What, is this all that my Heavenly Father has prepared for me? Think who I am; I am Mrs. Soandso." He said, "Well, Madam, I am very sorry indeed to have you feel this way, but I was on the committee in your case, and you had the most careful consideration, and really it was a most difficult task to build even this little log cabin out of the material you sent here to build with." And then she looked across the street and saw a beautiful mansion, and she asked, "Whose is that?" He replied, "Soandso's." She said, "Why, that is my gardener; how in the world could he have such a mansion as that?" And he replied, "That is the material he sent here to build with." (Applause.)

So the lesson here today is that each one of us should be sending out thoughts and deeds, such as we want our business, our homes, our schools, our city and our nation built of. If we have not been doing this, the time should be now that we begin to do so. I thank you. (Applause.)

President Gary: Mr. William P. Palmer, President of the American Steel and Wire Company, Cleveland, will now address us.

Mr. Palmer: Mr. President and members of the Institute: Frankly, I feel like a man out of a job. If I had

any ideas on the subject of impromptu speech-making, they have been anticipated and tramped over.

However, I would like to reinforce a thought that has been with me for some time. The present great prosperity in the iron and steel business, we certainly know, in large measure is built on the misery and misfortune of other people. Of course we will cash in, but it seems to me that we shouldn't have the future clouded. If we will only look backward and consider that history repeats itself in the matter of lean years and fat years, we might learn some lessons for the future.

We are certainly in the fat, but viewing the past, it would seem to me—and I shan't make the mistake of shoving the burden on any one department, we will go right clear up to the head—the iron and steel people are punk sellers. We don't get enough for our goods. Whether we don't know how or whether we don't intend to, is immaterial. The fact remains that four years out of every five, the buyer gets the better of the seller every time. I think that I myself have been in a blue funk when I have heard of the other fellows' prices, and we have gone them one better, and bye and bye we have all gone about ten degrees below the irreducible minimum. (Laughter and applause.)

Now, we are making big profits, all of us, to-day and to-morrow, but it is nothing of our making, it has happened to come to us. But can't we all learn some lesson? If we cannot regulate buying, and inasmuch as selling has been so beautifully unregulated, cannot we protect ourselves in some way? We all know that when the price is low people buy only what they absolutely need, and then load up when the price is advancing. They do this by "contract," and every man here knows that if the price would drop to-morrow such contracts are not worth the paper they are written on and that they are merely options. Something has got to be done. It can't be done to-night or to-morrow, but intelligent study will teach us the value of team work. If we all conduct our busi-

ness along this line, as Mr. Horner said, instead of each one for himself, we can secure a better return on our investment. (Applause.)

President Gary: We will now hear from Mr. James Inglis, President of the American Blower Company, Detroit.

Mr. Inglis: Mr. Chairman, when I was asked to speak at this dinner, I first thought of refusing, but am glad I did not, as I never heard a lot of frightened after-dinner speakers given such a reassuring send-off as we received to-night from the toastmaster. I view my limited abilities as a speaker somewhat as President Wilson does his beauty. I understand that he does not consider himself a handsome man—at least he didn't a few years ago. Perhaps since he has become such a successful wooer under the handicap of years, he has changed his mind. But a few years ago he put it in a limerick this way:

> "My face for beauty is no star,
> As it's easy to see from afar;
> But I don't mind it,
> Because I'm behind it—
> It's the man in front gets the jar."

I wish also to speak of the welfare work that has been so much the theme of previous speakers. I speak of it somewhat as an outsider. I am a member of the Institute, though I never knew just why. It is made up principally of the manufacturers of iron and steel, and just why we poor victims who have to buy your product at most extortionate rates are admitted to membership, I never understood. (Laughter.)

As to the welfare work, I think it is a matter of wonderful importance to the industrial progress and the prosperity of America that the iron and steel industry has taken such strides along this line and has blazed the way for every other manufacturer to follow. I blush to think of the time spent in years past, on the board of the Associated Charities, Children's Aid Society and such organi-

zations, while it never occurred to me that I had a family in my own works that I never did anything for. Since this movement started, it has been one of the most gratifying things to me to see what has been accomplished. A little attention paid to that work brings most gratifying results to the employer. Of course, all this work that is being done by manufacturers is looked upon now by some as a mere sop to head off the activities of agitators, but I think that will wear off because the employers, most of them, are not doing it from selfish motives and are in dead earnest.

We have in our town a citizen, more or less obscure, by the name of Henry Ford. It is not my intention to refer to his remarkable payment of a $5.00 minimum wage, or to his welfare work. I think his motives are most sincere in establishing that rate, and I think his views on fellowship are behind it. But I want to speak about his hospital. Recent numbers of the Institute Bulletin have devoted much space to the subject of hospitals. Just a word about what Mr. Ford is doing along that line in Detroit.

The Henry Ford Hospital now can care for 160 patients, but it is intended ultimately to have 2,000 rooms, every patient to have an individual room, at a maximum rate of $2.00 a day, including all medical and surgical attendance, and to provide hospital facilities for that great middle class that now have no means of getting it, as well as to the poor. He operates this hospital on somewhat original lines, as he has certainly introduced original methods in his manufacturing. For instance, the nurses do not live in the hospital at all. They work eight hours a day, and they are compelled to live entirely away from the hospital so as to come in fresh to their work. Later on it is his intention, I think, to have the internes do the same.

A hospital operated on such a plan, of course, will require an endowment of several millions, which I understand it is Mr. Ford's present intention to provide. So

far as I know, there is not another hospital anywhere based on this idea of taking care of patients who are only able to pay a very moderate sum and still would die rather than accept charity. Mr. Ford's plan proposes to fill the gap between charity cases and the ordinary hospital charges which, including medical and surgical attendance, are such as to make it necessary to discount earnings for years to follow.

In discussing the subject of hospitals, our minds naturally revert to the present conditions in Europe. The previous speakers have referred to the war. Of course, that is a subject that is in all of our minds all of the time. The side of the question that appeals to our sympathy comes first, but we naturally also consider, with some apprehension, perhaps, what business conditions we will be called upon to face when the war is over. Although it is largely a matter of guesswork and the experts disagree, we must be prepared, as far as possible, for rapid and perhaps unexpected changes in industrial conditions in this country. It will no doubt tax our ingenuity as it never has in the past to develop methods of efficiency in manufacturing, which may, of course, be supplemented by revised tariff laws, but aside from these aspects of the case our efforts should be directed to the maintaining of the most cordial relations with our employees, meeting in advance, so far as our conditions and profits will permit, all reasonable demands as to wages and working conditions, all of which is more or less related to or supplemented by this welfare work which has been so fully discussed here this evening. (Applause.)

President Gary: This completes the list of speakers prepared by the committee, but it does not exhaust either our time or our speaking talent. Whom else do you desire to hear from?

Cries of "Butler" and "Uncle Joe."

President Gary: Our trusty friend, Colonel Joseph G.

Butler, Jr., Vice-President of the Brier Hill Steel Company, Youngstown, is called for.

MR. J. G. BUTLER, JR.: Judge Gary and fellow members, and those higher up (looking at the gallery): Notwithstanding the enforced absence of our Director, Mr. Schwab, I feel that this is a joyous occasion. I have enjoyed it very much. These impromptu addresses where you get three weeks' notice are very valuable. (Laughter.) In the absence of Mr. Willis King, who usually has an impromptu address at hand, I have one here. (Taking paper from pocket.)

I wish to announce to this assemblage that here and henceforth we will have to address our worthy president as "Dr. Gary." I learned to-night for the first time that he has been made a Doctor of Laws by one of the oldest and greatest educational institutions in this country, Lafayette College. (Applause.) In view of the beautiful Biblical illustration that the Judge made this morning in his remarks, I think the next degree we will give him will be Doctor of Divinity. (Laughter and applause.)

We certainly have had an interesting day. I was greatly impressed with the moving pictures of the National Tube Company. I am pleased to compliment the gentleman at the head of the National Tube Company, Mr. W. B. Schiller, as a Brier Hill product, and all Brier Hill products are the very best. (Applause.)

I listened with a great deal of attention to Mr. Mather's discourse this morning. He told us of the city of Cleveland and its industries in a very comprehensive and illuminating way. It may not be known to all of you, it certainly is to some of us, that this meeting was originally intended to be held in Youngstown. As a matter of fact, the invitation had been voted upon and accepted; but after a careful consideration by our Youngstown associates, we thought that we were not able—at least some of us thought that we were not able—to take care of this vast number who have shown up here today. Now,

it seemed to me there was one way of doing this, which was to take care of what we could in our new hotel and then to throw the town open, with genuine Youngstown hospitality. I think, if I had had my way, that we would have given points to even Birmingham. But I was overruled, and the next question was where this fall meeting should be held. Now, I want to say to you that Cleveland was considered so appropriate a place that it didn't even have to apply for it, and that is why we have it here. (Applause.)

I haven't said anything about this carefully prepared speech. In view of the fact that we expected that this affair would be at Youngstown, I had prepared a few facts, and I am going to boil them down, and if the Judge will shake his gavel there, it will be all right, I will quit in just a minute. It is getting late, but I am going to tell you just a few things about Youngstown and its industries, in competition with Cleveland. (Laughter).

Youngstown is the heart of the greatest wealth-producing district in the United States. We have four great trunk lines of the country within an area of two hundred feet. On an area of three square miles, Youngstown being the center, is produced more iron and steel than on any other single area of the same size in the world. (Applause.) $200,000,000 are invested in manufactures, $123,000,000 in iron and steel, $10,000,000 more appropriated for additions to those steel plants—mostly Cleveland money. (Laughter.) In addition to that, many of you know that it is contemplated by the United States Steel Corporation to build at McDonald, a suburb of Youngstown, some additional mills. Mr. McDonald is very anxious to build these, and I am assured by Mr. Farrell that it is the intention to do it. I hope the finance committee of the United States Steel Corporation will take a few minutes off and appropriate about half an hour's income to this purpose. (Laughter.)

Youngstown's annual payroll is $35,000,000. We have,

in number, more parks in Youngstown than you have in Cleveland. Now, I haven't anything against Cleveland, but in view of the fact that this meeting should have been held in Youngstown, I want to tell you that we have one park that has more acres in it than all the parks together in Cleveland. (Laughter and applause.) We have a 36-hole golf course—you have to go around it twice to make it. (Laughter.) The Mahoning and Shenango Valleys produce one-fourth of all the pig iron made in the United States. (Applause.) Incidentally let me say this: Gentlemen have talked here about contracts being options. I want to say to you, in all earnestness, that that is the fault of the seller and not of the buyer. I have been selling pig iron for more than a half a century, and in all my experience I never yet made a pig iron contract that wasn't carried out literally. (Applause.)

By the way, I think I have already mentioned that Mr. Mather made a very illuminating and comprehensive address this morning. He told about the increase in Cleveland's population. In 1860, Youngstown contained 2700 people, in 1915, 115,000, a very much greater per cent. increase than that of Cleveland. (Laughter.) The birth rate in Ohio, by the authorities, is the largest of any state in the Union, and at least 99 per cent. is pure, the real thing, legitimate. We contribute our full share at Youngstown. (Applause.)

Speaking of Cleveland, Cleveland has, according to a Chamber of Commerce leaflet, 43 of the most modern blast furnaces in the country, located within 65 miles of its Public Square. (Laughter.) In Youngstown which, as many of you know, is half-way between Pittsburg and Cleveland, if I should undertake to give you the same kind of statistics, we have got within 65 miles of Youngstown 185 blast furnace plants. (Laughter and applause.)

There are other gentlemen here that have been notified that they are to be called on. I thank you sincerely for the attention you have given me. (Applause.)

President Gary: Whom will you have next?

Cries of "Hoyt."

President Gary: Our old friend, James H. Hoyt, of Cleveland, is called for.

Mr. Hoyt: Mr. President, ladies, and gentlemen: What the previous speaker has said concerning Mr. Henry Ford and the Ford motor car reminds me of a story of an Irishman. A friend of his asked him how he was getting along. "Foine," said he. "I'm doin' foine, but I don't want many people to know what I am doin'." "Why not?" said his friend. "Because I'm agent for the Ford motor car, and it would break me mother's heart if she found it out. She thinks I'm tendin' bar." (Laughter.)

Years before Judge Gary began his essential labors for the benefit of the business world, years before he began to preach the gospel of "Peace on earth, good will toward men" in business matters, Thackeray anticipated one of the things the judge said to-night in introducing the impromptu speakers. The great novelist said, you will remember, "How witty one can be at a dinner party the day after." (Laughter.)

When this association was first formed, if I recollect correctly, it was suggested by a periodical of the "yellow dog" variety, published in the great metropolis, that all those were eligible for membership in the Institute who "make iron and steal for a living." (Laughter.) Thackeray says, to quote from him again, "Definitions never are complete," and this one is not accurate, because there are very many of us, earnest and enthusiastic members of the Institute, who, whatever else we may do, do not make iron! (Laughter.)

And the reason why we are members of this great association is obvious. It is because the industry which you gentlemen represent is the very heart of the great complicated commercial organism which we call business. The iron and steel trade is the barometer. When it goes up, we go up with it; and when it goes down, we go down too, whatever may be our vocation. When the

great heart is sound and doing its work effectively, its bounding pulses send inspiration to every remote portion of the great organism, but when the heart languishes and grows weary and weak, as it has for the last few years, then the whole great body becomes feeble and inefficient, and suffers even to its very extremities. In other words, when you gentlemen, who represent your great industry, are prosperous, then the men of every other calling are prosperous, too. I won't even except the clergy. (Laughter.) At any rate, I won't except those members of the sacred profession who are true to their high calling, who decline to sacrifice sanctity to sensationalism, and who do not bother themselves very much about woman's fads and fancies and fashions, and who do preach the gospel according to St. John. (Applause.) They are the ones who get an inspiration from your example, not only from your thrift and economy, but from your helpfulness to others, even though they may be competitors—because under the wise guidance of your President, I think that, more than any other class of men I know, you obey St. Paul's injunction, "Be not slothful in business, fervent in spirit, serving the Lord." (Applause.)

Now, during the last two cold and cruel winters, Judge Gary has been predicting the coming of prosperity every six months at each semi-annual meeting of the Institute. The fulfillment of his prophecy has been delayed somewhat, but "all things come to him who waits," and it looks now as if his prophecy were really coming true, for the sun of prosperity has risen above the horizon, and we are all, in a way, basking in its beams and rejoicing in their genial warmth. But, as has been said here this evening, our rejoicing is tempered by a poignant and sincere regret, for the reason that the dreadful war which is being waged abroad has, to a certain extent, taken the place of a proper and intelligent protective tariff, and, to that extent, the sufferings of others have inured to our benefit and comfort. It is a pleasant thing

that your furnaces are in full blast, and the hum of your machinery is grateful to our ears. And yet, amid the noise and buzz of your thriving business, we cannot shut our ears to the wailing and weeping of dishonored and widowed women, to the cry of maimed and orphaned children, and to the groans of the wounded and the dying. The horrors of the war are fittingly represented by a single incident, which is the climax, as it were, of its brutality and savagery. Only last week a nurse, Miss Cavell, having been tried by court-martial at five o'clock in the afternoon, was shot to death at sunrise on October 12th, by a file of soldiers. With the highest and most exalted courage, she declined to be blindfolded, and she stood up before the firing squad undaunted and unafraid, and met death with a heroism worthy of the noblest and the highest place. (Applause.)

I am glad that I belong to a country in which such a brutal and savage deed of shame would be impossible. There are no soldiers in the American army, as now constituted or as hereafter enlarged, who could be found to fire at a defenseless woman, whoever ordered them to do so; no officer in the American army could be found who would give such an order, and no American court-martial could be constituted that would record such a brutal and hideous decree. (Applause.)

While we are to an extent gainers by the war, others are greatly suffering by it. As Mr. Kennedy has said, there is not a man here who does not wish and hope that the dreadful carnage will cease, regardless of any profits he may make as a result of it. (Applause.) It therefore becomes important for us to see to it that our industries are protected and aided when the war ceases; protected not by death and destruction and suffering, but by a proper and judicious protective tariff. (Applause.) And we ought to see to it that this great question of the tariff is no longer a football of the politicians, is no longer passed upon by men who care for votes rather than for sound and proper business pros-

perity. The tariff is not inherently, and should never be, a matter of party politics, because the welfare of the whole country, to whatever party its citizens belong, depends on a wise and proper tariff. It has been well stated over and over by Ex-President Taft, and by our own Mr. George W. Perkins, that a tariff commission of experts should be established, who know the needs of the country and its necessities, and that this commission should make suggestions to Congress to lower the tariff rates wherever necessary, and to raise them wherever necessary, in order to protect the great industries of this country. Unless this is done, when the war is over your business and our business will languish again, for if we would succeed commercially, the well paid and intelligent labor of America must be protected against cheap labor from abroad. (Applause.)

It seems to me that there are a good many signs of encouragement. In the first place, we have at last recognized somebody in Mexico. Whether his moral character is all that we might wish is another question; but at any rate, he has been recognized, and that is something. In the next place, Mr. Bryan seems to have been eliminated. There is a world of gladness in the thought. He talks about going abroad, you will remember, in order that he may, with his persuasive and practical eloquence, induce the warring nations over there to drop their arms and make a permanent peace. I think he ought to go. Such an appeal from him would be very effective. He could undoubtedly touch the heart of the Kaiser, if any man could. I think his plea for peace would be as effective as a plea for "safety first" made by a fly on the rim of the hind wheel of a sixty horse-power motor going at the rate of seventy miles an hour would be. (Laughter.)

In the next place, the administration seems to have had a change of heart on the subject of national defense. Even Mr. Daniels thinks our navy ought to be improved, and the President has committed himself to a larger

army and a better navy. I do not disagree with Mr. Kennedy when he argued against having too much armament. He qualified his remark by the use of the word "unduly," and I agree with him. We do not need a navy or an army unduly large, but we certainly do need both a navy and an army large enough to properly protect us in case of aggression. (Applause.) I am not anxious that our country should go to war, nor do I think that any other American citizen is anxious for that dreadful contingency; but I do believe, and I think the majority of Americans believe with Washington, that the way to prevent war is to be prepared to repel aggression. We have no desire to take any other country's territory. We are not in favor of spending one cent for aggression, but I do believe that we are ready and willing to spend millions for defense. (Applause.)

This great country ought to be in the position of Mr. O'Connor. Mrs. O'Connor lived in a house adjoining that of Mr. McCarty, and went down in her back yard one Sunday morning and found her neighbor busily writing something on the fence. "The top o' the marnin' to you, Mr. McCarty," said Mrs. O'Connor. "You seem to be workin' very hard on Sunday, the blissed Lord's day." "I am," said Mr. McCarty. "I have a long and hard job before me." "What may ye be doin', Mr. McCarty?" said Mrs. O'Connor. "I am writin' down," said Mr. McCarty, "the names of all the men in this ward that I can lick." "Well," said Mrs. O'Connor, "that ought not to take you long." "Oh, yes it will, it will keep me busy all day." "Is O'Connor's name there by any chance?" she asked. "Is O'Connor's name there?" said McCarty, "it heads the list." "Oh, does it," she said, "I'll have to see about that." So she rushed into the house and awakened O'Connor, and said to him, "McCarty do be writin' on the fence the names of all the men in the ward he can lick." "Is my name there?" said O'Connor. "It heads the list," said Mrs. O'Connor. "Holy smoke," said O'Connor, "I'll

have to see about that.'' So he put on his shoes and his coat and went down and said, ''You seem to be busy this holy day, McCarty.'' ''Yes,'' said McCarty, ''I have a long and hard job before me.'' ''What may ye be doin', McCarty?'' ''I am writin' down the names of all the men in this ward I can lick,'' said McCarty. ''That you can lick?'' said O'Connor. ''I am,'' said McCarty. ''Is my name there, McCarty?'' ''It heads the list,'' said McCarty. ''The divil it does,'' said O'Connor, and taking off his coat he jumped over the fence and said, ''McCarty, you can't lick me. You can't lick one side of me.'' ''Are ye sure of that?'' said McCarty. ''I am so sure of it,'' said O'Connor, ''that I am ready to prove it to you this minute.'' ''Then,'' said McCarty, ''I'll lave your name off.'' (Laughter.)

I am sick of American bluster and brag. It seems to me that unless we are careful, our national life will be innoculated with the poisonous virus of complacency. I want our country to be in a position such that when any other nation is making up a list of the nations it can lick, it will ''leave off'' the United States of America. (Applause.)

Our motto is not ''to grab and to keep,'' but our motto should be ''to have and to hold what the fathers fought for,'' and in order to do this, gentlemen, we must be adequately and properly prepared. (Applause.)

President Gary: Judging the present from the past, I had supposed some of the speakers to be called upon, at least, were inexperienced, but I find they are all old stagers. Therefore, I withdraw my remarks. Now the meeting is yours. It is your privilege to call on any one to speak. And now, gentlemen, whom will you have?

Cries of ''Farrell.''

President Gary: Mr. James A. Farrell, chairman of the Committee on Program is called for.

Mr. Farrell: Mr. Chairman and gentlemen: On behalf of the Committee on Arrangements I desire to ex-

press the thanks of the committee to those gentlemen who have so ably presented the papers today and to those who discussed them, and to those who spoke this evening. The membership of this Institute are enabled through these semi-annual meeting to interchange opinions concerning metallurgical and commercial subjects and by the fruits of their experience benefit each individually and the industry as a whole.

The committee have had some difficulty from time to time in securing a suitable number of papers for each meeting, and at times the committee is obliged to obtain these papers, I might say, by conscription. And the committee suggests that for the next meeting, in May, 1916, suggestions concerning subjects and titles of papers be submitted to Secretary McCleary, and the committee will endeavor to keep in view the fact that it is the desire of the Institute to have not only practical papers, but papers representing the live subjects of the day. (Applause.)

The meeting in Cleveland has been, I think, one of the most successful in the history of the Institute. The papers were certainly of a very high order, and indicated that great care was displayed in preparing them. It is to be hoped that the research work that is going on in the industry will continue, and that at our next meeting we will have papers that will be equally as well considered as those which we have heard to-day. (Applause.)

President Gary: What is your further pleasure, gentlemen?

Mr. Willis L. King was called for.

Mr. King: Mr. Chairman and gentlemen of the Institute: I am certain that we all feel repaid for coming here, at whatever inconvenience and cost, in hearing the address of our President and the many interesting and valuable papers read by the members of the Institute. I can speak for the officers and directors when I say that their efforts are greatly appreciated.

The authors have given their time, talents and experience freely for the benefit of the general steel industry and it is our hope that they may feel repaid, at least in some measure, in the consciousness that they have added something valuable to the sum total of scientific and practical knowledge of the steel art.

Our president's address was, as always, an inspiration to us. His knowledge, experience and qualities of mind admirably fit him to advise us. On a memorable occasion some years ago I said that we respected and loved him because he practices what he preaches, for when he sets up a high standard of business morality he asks us to follow, not precede him.

In his address this morning he touched upon the most interesting question of the day to business men, "When will the war end, and how then will business be affected?"

Perhaps it is a wise limitation imposed upon us that the present only is within our grasp and that we may only judge the future by the past. Herein lies the difficulty, for there is no precedent for this titanic war, and we must await the result with what patience we may. It is probable that in time we must bear our share of this great economic waste; but for the present, while we do not desire to thrive on the misfortunes of others, and regret that we are indebted to the war rather than to healthy and normal conditions at home, yet a large part of the world is dependent upon us for its commercial needs in steel and other commodities, and we cannot do less than accept this opportunity thrust upon us at a time of depression in the domestic market.

However, it seems reasonable to expect that, when the peoples of Europe, now at war, return to peaceful occupations, their attention and activities will be directed first to the re-establishment and expansion of their export trade. Lack of capital will prevent for years the replacement of the vast properties destroyed during the conflict, and they must acquire inflowing capital from exports.

When that time arrives, they will find in this country an obliging tariff law right at their hand, unless in the meantime repealed. In my opinion, we must set our house in order against that time by putting into effect a protective tariff, and this I believe will be done at the coming election, notwithstanding the efforts already being made to becloud the real issue. (Applause.) When we last met six months ago, there were some indications of a revival of business, which have since been verified in full measure, and much, I think, beyond our expectations. Our order-books are full for many months, and our production is inadequate to meet the demand. The near future, and I mean by that one year or more, seems to be assured. Let us then be thankful for this measure of prosperity, but with the same spirit of obedience to law and decent regard for our neighbors and the public shown during the many lean years and trying times of the past. (Applause.)

President Gary: Gentlemen, for your interest in and your loyalty to the Institute I thank you. You have established a high reputation in the business world. You are considerate of the interests of all others. Do not forget one another. Notwithstanding our sharp competition in business, remember, gentlemen, we are friends, we are affectionate friends. We like to help each other, and we should help each other in every possible way. This Institute is our home. We come together here trusting one another, loving one another, wishing the best prosperity to each other; and so long as we hold the feelings for each other which we now possess, we may be certain that the Institute will prosper. I bid you good-night. (Applause.)

PARTICIPANTS—MAY MEETING

A

Affelder, Louis J.
Affleck, B. F.
Ahles, R. L.
Alder, T. P.
*Alford, W. J.
Allaway, Thomas W.
Allen, Anson W.
Alley, James C.
*Allison, J. Wesley
Armstrong, Eliot
Atcherson, R. W. H.
Atwater, C. G.
*Atwater, R. M., Jr.

B

Baackes, Frank
Bacon, C. J.
Bailey, Edward
*Baillie, A.
Baldwin, R. L.
Ball, W. H.
Baldridge, W. H.
Balsinger, W. R.
Barbour, Henry H.
Bartol, Geo.
*Bateman, J. G.
Battelle, J. G.
*Baylie, F. N.
*Belsterling, Charles S.
*Bennett, C. F.
Bennett, C. W.
*Bennett, W. H.
Bent, Quincy
Bentley, A. J.
*Bergquist, J. G.
Biggert, C. F.
Black, H. F.
Block, L. E.
Boley, Ernst, Sr.
*Boley, Ernst, Jr.
Bolling, Raynal C.
Bope, H. P.
Bourne, B. F.
Boutwell, R. M.
Bowen, Arthur P.
*Bowen, James R.
Bower, W. C.
Bowler, R. P.
Bowman, F. M.
Bowman, L. H.
Bowron, James
Bradley, John C.
Braine, D. L.
Braman, H. S.
Brassert, H. A.
Brock, John Penn
Brooks, J. J., Jr.
Brown, Fayette
Browne, D. B.
Buck, C. A.
Buck, D. M.
Budd, R. B.
Buffington, E. J.
Burden, J. A.
Burleigh, George W.
Bush, D. Fairfax
Bush, Harry D.
Butler, Joseph G., Jr.

C

Campbell, J. A.
Campbell, L. J.
Campbell, R. G.
Carhart, P. E.
Carnahan, R. B., Jr.
Carroll, Walter C.
Carse, David B.
Carse, John B.
*Cederquist, M. O.
Chamberlain, H. S.
Charls, G. H.
Christ, E. W.
Clark, Eugene B.
Clark, R. W.
Clarke, E. A. S.
Clarke, Thomas C.
*Clendenin, J. C.
Clingerman, W. H.
Clopper, H. G.
Close, Charles L.
Cluff, Charles C.
*Cohen, Fred W.
Coles, T. B.
*Comstedt, J. F. A.
*Cone, John J.
Connell, F.
Connors, G. W.
Cook, Edgar S.
Cook, Howard H.
Cooke, D. W.
Cornelius, H. R.
*Cotter, Arundel
Coulby, Harry
Crabtree, Fred.
Cragin, G. A.
*Crane, William M.
Crawford, George G.
Crawford, W. D.
Crispin, M. Jackson
Crocker, George A., Jr
Cuntz, W. C.
*Curry, H. M., Jr.
Cushman, A. S.

D

Dalton, H. G.
Darlington, Thomas
Davies, George C.
Davis, C. C.
Davis, Henry J.
Davis, S. A.
Day, R. D.
Dean, William T.
Decker, O. S.
Deericks, Joseph G.
Dette, William
Devens, Henry F.
*Dice, A. T.
*Dickey, W. C.
Dickson, W. B.
Diehl, A. N.
Dillon, A. H.
*Dillon, A. S.
Dinkey, A. C.
Dix, John W.
*Dixon, Edward M.
Dodd, Alfred W.

Donner, Robert N.
Donner, William H.
Dows, David
Driscoll, Daniel J.
Duncan, John
Dunn, J. J.

E

Eaton, C. D.
Edwards, J. E.
Edwards, V. E.
Evans, Mason

F

Fackenthal, B. F., Jr.
Farrell, W. H.
Faris, Jacob M.
Fedder, W. P.
Felton, E. C.
Findley, A. I.
Fletcher, John F.
*Flickinger, E.
Floersheim, B.
Forbes, William A.
Fowler, A. A.
Francis, L. W.
Freeman, S .S.
Freyn, H. J.
Froment, Eugene McK.
*Froment, Frank L.
Fuller, Willard

G

Gardner, William
Gary, Elbert H.
Gathmann, E.
*Geddes, F. B.
Gensheimer, Philipp
George, Jerome R.
Gessler, Theo. A.
*Glass, George
Gleason, W. P.
Gordon, Frank H.
Grace, E. G.
*Grady, Charles B.
Graham, Charles J.
Gray, J. H.
Greenawalt, J. E.
*Greene, James W.
Gregg, Robert
Gresham, W. B.
Griffiths, E. S.

H

Hagar, E. M.
Hall, R. S.
Hamilton, Edward J.
Hammond, James H.
Handy, J. O.
Harrison, Edwin W.
Harrison, H. T.
Hart, Charles
Hatfield, Joshua A.
*Hay, Henry G.
Hayes, Will L.
Heedy, Henry W.
Hendricksen, J. J.
Henshaw, John O.
Hickok, Charles N.
Higgins, H. E.
*Higgins, W. B.
Hildrup, William T., Jr.
*Hill, P. S.
Hillman, Ernest
Hirschland, F. H.
Hobson, Robert
Holloway, W. W.
Holmes, C. O.
Howe, Henry M.
Hoyt, James H.
*Hughes, Edward P.
Hughes, John
Hunter, John A.
Huntley, F. P.
Hurd, Charles S.
Huston, A. F.

I

*Isaacs, M.
Isham, Phillips

J

Jay, John C., Jr.
Jeffrey, J. W.
Jewett, G. W.
Johnson, J. E., Jr.
Johnston, C. T.
Jones, Evan F.
Jones, H. L.
Jones, Jonathan R.

K

*Kahil, A. A.
*Kaul, J. L.
Kauffman, W. L.
Kennedy, J. J.
Kennedy, Thomas W
Kenney, Edward F.
Ker, Severn P.
Kimball, G. C.
King, Willis L.
Kneeland, Edward
Knowles, Morris
Knox, Luther L.
Kreps, J. E.

L

Lamont, R. P.
Lanahan, Frank J.
Langenbach, Edward A.
Leet, George K.
Lehman, A. C.
Lemoine, L. R.
Le Van, G. B.
Lewis, J. E.
Lewis, John F.
Lewis, R. A.
*Lomax, C. S.
*Long, S. C.
Lustenberger, L. C.

M

Maccoun, Andrew E.
Macdonald, Duncan C
Maeder, C. E.
Manning, William E.
Marshall, C. D.
Marshall, C. S.
Mather, S. L.
Mathews, John A.
MacDonald, R. A.
McAlarney, J. H.
McAteer, H. W.
*McCauley, John E.
McCleary, Elmer T.

McCleary, James T.
*McClintic, H. H.
McDonald, Thomas
McElhany, C. B.
*McIlravey, W. N.
McIlvain, Edward M.
McKay, George F.
McKelvy, E. A.
McKenna, A. G.
McLeod, John
McMaster, Ross H.
McMillen, A. K.
Meissner, C. A.
Merriman, D. A.
Mesta, Geo.
Miller, C. D. S.
Miller, C. L.
Moffett, C. A.
*Mohr, G. K.
Morgan, W. H.
Morris, A. F.
Morris, L. B.
Moss, John B.
Mudge, E. W.
Murray, Thomas

N

Nash, A. L.
Nash, H. P.
Neckerman, William M.
Neeland, M. A.
*Nevin, John
Ney, Robert W.
Nichols, J. A.
Nicholson, J. H.
Nicoll, Benjamin
Niemann, C. F.
Noland, Lloyd
Norris, G. L.
Nullmeyer, Frank H.

O

O'Bleness, H. M.
Orrok, George A.
Ottinger, Walter S.

P

Palmer, W. P.
Palmer, W. R.
Pargny, E. W.
*Parker, J. A.
*Parks, G. Elton
Peckitt, Leonard
Penton, John A.
Perkins, George W.
Perkins, H. F.
Perley, W. B.
Peters, Richard, Jr.
Petinot, N. G.
Pew, John O.
Pigott, William
Pilling, George P.
Pilling, W. S.
Poor, F. A.
Pope, C. E.
Porter, J. W.
Post, George A.
Pratt, R. H.
Prendergast, G. A.

Q

Quarrie, B. D.

R

Radford, Robert
*Ramsburg, C. J.
Rand, Charles F.
Raymond, H. A.
*Rees, Charles P.
Reeves, David
Reilly, W. C.
Reis, Geo. L.
Reis, John
Replogle, J. Leonard
Reynders, J. V. W.
*Rianhard, Thomas M.
Rice, Richard H.
Roberts, Frank C.
*Robins, A. C.
Robinson, C. S.
*Robinson, D. P.
Robinson, T. W.
Roe, J. P.
Roebling, K. G.
Ross, L. P.
Rowe, Wallace H.
Ruiloba, J. A.
Runyon, Walter C.
Russell, N. F. S.
Rust, H. B.
Rust, W. F.
*Ryan, Alan A.
Ryerson, Joseph T.
Rys, C. F. W.

S

*Sage, Ralph V.
*Saladin, E.
Samuel, Frank
*Sanders, Frank M.
Sauveur, Albert
Schiller, William B.
*Schoonmaker, A.
Schnatz, G. T.
Schwab, Charles M.
Scott, G. C.
Scott, Isaac M.
Seaman, Joseph S.
Sheadle, J. H.
Sheridan, R. B.
Sherer, J. Norman
Shiras, MacGilvray
Sias, J. M.
Siebert, W. P.
Slick, E. E.
Slick, F. F.
Sloan, Burrows
Smith, C. C.
Snyder, W. P., Jr.
Souder, Harrison
*Spilsbury, E. G.
Sproul, William C.
Stackhouse, Powell
Stanton, W. A.
*Stark, C. J.
Stebbins, H. S.
Stevenson, A. A.
Stewart, Hamilton
Stewart, Scott
Stillman, J. S.
Stone, Charles F.
Stone, E. E.
Sullivan, G. M.
*Sullivan, J. J., Jr.
Sullivan, W. J.
Sweetser, Ralph H.

T

*Taylor, H. P.
Taylor, Knox
Taylor, T. H.
Taylor, W. A.
Taylor, W. H.
Tener, Robert W.
Thomas, A. J.
Thomas, C. S.
Thomas, E. P.
Thomas, George, 3d
Thomas, L. E.
Thomas, T. E.
Thomas, W. A.
Thompson, A. W.
*Thompson, Lynn W.
Thorp, George G.
Thropp, J. E., Jr.
Tinsley, John F.
Tod, Fred.
*Todd, E. G.
Topping, John A.
Townsend, J. Fred.
*Townsend, W. H.

U

Unger, J. S.

V

Verity, George M.
Vogt, A. W.

W

Waddell, J. D.
Waldeck, Jay
Walker, J. C.
Walker, W. R.
Walker, W. H.
Wallingford, B. A., Jr.
Ward, James H.
*Washburn, F. W.
Watson, W. E.
Wayland-Smith, R.
Weaver, H. B.
*Weidman, Hugo
Weir, D. M.
Weir, E. T.
*Weiss, Jay G.
Wellman, S. T.
Westfall, H. D.
Wheeler, Seymour
White, G. A.
Whitton, F. H.
*Wicks, J. C.
Wight, S. D.
Wilkinson, Horace S.
Wilputte, Louis
Witherbee, F. S.
Wolfe, William Lloyd
*Wood, Alan D.
Wood, Frederick W.
Wood, Richard G.
Wood, Walter
Woods, John E.
Woods, Leonard G.
Worth, E. H.
Worth, W. P.

Z

Ziesing, August
Zehnder, C. H.

* Guests

PARTICIPANTS—OCTOBER MEETING

A

Abbott, Franklin E.
Abell, O. J.
*Abell, R. T.
Affleck, B. F.
Allderdice, George F.
Allderdice, Taylor
*Allen, J. N.
Allen, James P.
Alley, James C.
*Andersen, R. B.
Anderson, B.
Andresen, H. A.
Andrews, J. I.
Andrews, J. M.
Andrews, M.
Armour, M. C.
*Ashley, John S.
Atcherson, R. W. H.

B

Baackes, Frank
Backert, A. O.
Bacon, C. J.
Baily, Thaddeus F.
Baird, D. B.
Baker, George
*Baker, Henry F.
*Baldwin, George S.
Baldwin, H. G.
Ball, W. H.
Balsinger, W. R.
Baltzell, Will H.
Banks, A. F.
Barren, H. B.
Barrett, Jacob C.
Bartol, Geo.
*Bassert, J. P.
Bates, Joseph R.
*Battin, W. I.
Beale, A. H.
Beatty, R. J.
Beaumont, George H.
Bennett, C. W.
*Bennett, W. H.
*Bentley, A. J.
Bentley, F. T.
Bergquist, J. G.
*Betz, A. B.
*Bever, Clarence
Bever, J. J.
Billings, F.
Bingham, H. P.
Black, Herbert F.
*Blake, S. J.
Block, L. E.
Bodwell, H. L.
*Boes, F. J.
Boley, Ernst, Sr.
*Boley, Ernst, Jr.
*Boller, W. S.
*Bolton, Chester C.
*Bool, Samuel E.
Booth, Carl H.
Bope, H. P.
*Bosley, H.
Bourne, B. F.
Bourne, Henry K.
Bowman, F. M.
Bowman, L. H.
*Bowne, W. K.
*Boyd, Edward H.
*Boyd, J. K.
Boynton, A. J.
Boynton, D. S.
Brainard, J. W.
Brassert, H. A.
Bray, T. J.
Brooke, Robert E.
*Brooks, Clyde
Brooks, J. J., Jr.
Brown, Alexander C.
Brown, Charles M.
Browne, D. B.
Brunke, Frederick C.
Buck, D. M.
Buek, C. E.
Buffington, E. J.
Burden, James A.
Burdick, W. P.
*Burke, Edmund S., Jr.
Bush, D. Fairfax
Butler, Gilbert
Butler, Joseph G., Jr.

C

*Cagwin, T. P.
*Calhoun, Patrick
Camp, J. M.
Campbell, J. A.
Campbell, L. J.
*Campbell, J. W.
*Cannon, A. V.
Carhart, P. E.
Cartwright, J. H.
*Cary, H. L.
Chamberlain, H. S.
Champion, D. J.
Chandler, John C.
Charls, G. H.
*Chisholm, A. T.
Chisholm, Alvah S.
Chisholm, Henry
*Clapp, R. G.
*Clarage, E. D.
Clark, E. B.
Clarke, N. J.
*Clement, Harold
Cluff, Charles C.
Clyde, William G.
Coakley, John A.
*Coburn, F. Ward
Coffin, William C.
*Cole, C. E.
Collard, George L.
Collier, William E.
Collins, E. C.
*Collins, Wm.
Comstock, W. S.
Conner, A. L.
*Connelly, E. K.
*Converse, E. A.
Cook, Edward B.
Cook, Howard D.
Cook, Howard H.
*Cooper, F. G.
*Cope, F .T.
Cordes, Frank

Cornelius, H. R.
Cornelius, William A.
*Cottingham, W. H.
Coulby, H.
Crane, T. I.
Crawford, E. R.
Crawford, W. D.
*Creveling Guy C.
Cromlish, A. L.
Cromwell, J. C.
Crowell, B.
Croxton, D. T.
Croxton, S. W.
Cushman, A. S.
Cushman, H. D.

D

Dailey, C. I.
Dalton, H. G.
Davies, Geo. C.
Davis, Charles C.
Davis, W. O.
Day, Rodney D.
Dean, W. T.
Decker, Omar S.
De Forest, A. T.
Deetrick, J. W.
Deming, Fred C.
Dempsey, James H.
*Denison, R. F.
Denton, I. H.
Deutsch, Samuel
Devens, H. F.
Deverell, H. F.
Dewey, Bradley
Diehl, A. N.
Dillon, A. H.
Dix, John W.
Dodd, Alfred W.
*Dorman, P. O.
Dougherty, J. W.
Dows, David
Driscoll, D. J.
*Duff, Harry E.
Duncan, John
*Duncan, W. M.
Dunham, L. E.
*Dunlevy, D. W.

E

Edwards, J. H.
Edwards, V. E.
Egan, F. D.
Elliott, C. H.
Elliott, L. H.
*Emmerton, F. A.
Eppelsheimer, D., Jr.
Estep, H. Cole
*Esterbrook, C. C.
Evans, David
Eynon, David L.
Eynon, David L.

F

Fairbairn, C. T.
Faris, J. M.
Farrell, J. A.
Farrell, W. H.
Fell, Charles
*Fickinger, P. J.
Findley, A. I.
*Findley, Emerson
*Fitzgerald, Chas.
*Fleming, J. N.
*Fleming, William J.
Fletcher, John F.
Floersheim, Berthold
Follansbee, W. U.
Forbes, William A.
*Forbes, W. H.
Foster, J. H.
Francis, Lewis W.
Frantz, J. H.
Fraser, J. S.
*Frease, George B.
Freeman, S. S.
Freyn, H. J.
*Froggett, J. F.
*Fuller, B. D.
Fuller, Willard
*Furst, E. W.

G

Galvin, John E.
Gardner, Wm. C.
Garry, A. H.
Gary, Elbert H.
Gathmann, Emil
Gayley, James
Gedge, Frederick C.
Gerry, Roland
*Gideon, F. A.
*Gilkey, E. Howard
Girdler, T. M.
*Glass, John
Gleason, W. P.
Glenn, Thomas K.
Goodspeed, G. M.
*Gordon, G. C.
Gordon, P. J.
*Gould, Frank
Gray, J. H.
Gray, L. J.
Green, W. McK.
Griffiths, Edwin S.
*Griffiths, F. J.
Grose, James H.
Grugan, Justice
Gruss, William J.
*Guernsey, J. B.

H

Haarbye, S. B.
*Hackett, S. E.
Haggerty, H. W.
Hall, R. S.
Hamilton, Alexander K
*Hamilton, F. B.
*Hamill, Laurence
Hammond, James H.
Handy, J. O.
Hanlon, W. W.
Harris, W. A.
*Harris, F. C.
*Harrison, G. L.
Harrison, H. T.
Hart, Charles
Harvey, A. F.
Hatfield, J. A.
Hayes, Will L.
Hazeltine, B. P.
Heberlein, F.
Heedy, H. Glen
*Henderson, John M.
Hendricksen, J. J.

*Herr, D. D.
Hess, Henry
Hewitt, Geo. W.
*Heywood, C. E.
Hickok, Charles N.
Hickox, Wilson B.
Higgins, H. E.
Higgins, W. B.
*Hill, W. H.
*Hillman, Ernest
Hitchins, E. S.
Hitz, Albert W.
*Hoag, M. L.
Hobson, Robert
Holloway, W. W.
Holmboe, L. C. B.
Holmes, G. C.
Horner, W. S.
Horton, H. E.
*Hotchkiss, C. W.
House, Allan C.
*House, George W.
Howard, Clarence H.
*Howell, A. E.
Howell, H. P.
Howland, H. P.
Hoyt, James H.
Hubbard, P. H.
*Huessner, K.
Hughes, I. Lamont
Hughes, William H
Hull, E. B.
Hunt, A. R.
Hunter, John A.
Hurd, Chas. S.
Hutchinson, B. E.
*Hutchinson, C. S.
Hutchinson, O. N.

I

*Ingersoll, G. R.
Inglis, Jas.
*Inglis, R.
Ireland, R. L.
Irons, Robert H.
Irvin, W. A.
Isham, Phillips
Ives, E. L.

J

Jackson, P. R.
James, Henry L.
Jarecki, Alexander
Jay, John C., Jr.
Jenks, George S.
Jewell, William E.
Jewett, G. W.
Johnson, Frank H.
Johnson, J. E., Jr.
*Johnson, Lewis
Johnston, C. T.
Jones, E. B.
Jones, G. H.
Jones, Harold C.
Jones, Harry R.
*Jones, I. O.
Jones, John E.
Jones, R., Jr.

K

Kagarise, John W.
Kauffman, W. L.
Kaufholz, C. F.
Kaufman, H. L.
Keefe, John S.
Kelly, H. M.
Kennedy, Hugh
Kennedy, Julian
*Kennedy, J. H.
Kennedy, J. J.
Kennedy, Thomas W.
Kenney, E. F.
Kernohan, R. B.
Ker, Severn P.
*Kilgore, R. M.
Kimball, G. C.
King, H. W.
King, Willis L.
*Kinney, A. T.
Kirk, Robert C.
Kittredge, J. P.
Klugh, Bethune G.
*Knight, W. W.
Knox, Luther L.
Koch, H. J.
Kranz, W. G.
Kreitter, J. W.
Kreps, J. E.

L

Lally, A. M.
Lanahan, Frank J.
Landgrebe, K.
LeBarre, R. S.
Lee, Leif
Lea, Robert C.
Lees, John W.
Leonard, Z. B.
Le Van, G. B.
Lewis, J. E.
Lewis, John F.
Lippincott, James
Llewellyn, P. P.
Llewellyn, J. S.
Long, J. H.
*Loree, L. F.
Lorenz, Fred W.
Lozier, Charles E.
Lukens, W. W.
Lustenberger, L. C.

M

MacDonald, R. A.
*McCauley, J. E.
McCleary, James T.
*McCloy, J. H.
McConnell, John
*McCracken, F. T.
McCullough, C. H., Jr.
McDonald, J. A.
McDonald, L. N.
McDonald, Thomas
McKay, George F.
McKee, A. G.
McKee, Walter C.
McKelvy, E. A.
McLauchlan, Jay C.
McLauchlan, William
McLeod, John
McMahon, R. E.
McMath, F. C.
McMillen, A. K.
McMurray, Max
Maccoun, A. E.
*Maltby, R. B.
*Mandell, H. H.
Manning, William E.
*Marchant, C. R.

*Marshall, D. J.
Martin, C. W.
*Marston, C. I.
Mather, Amasa S.
Mather, Samuel
Mather, S. L.
Mather, Wm. G.
Meacham, D. B.
*Meek, G. S.
Meissner, C. A.
*Menke, Paul D.
Mercur, Robert J.
*Merriman, A. T.
Merriman, D. A.
Miller, C. D. S.
*Miller, Charles W.
Miller, L. B.
Mills, E. S.
Mills, J. R.
Mitchell, John
Mitchell, R. D.
Mogan, C. J.
Montgomery, C.
*Moon, D. C.
*Moore, Henry
Moore, V. Mumford
Moran, P. J.
*Morey, A. T.
Morgan, W. H.
Morris, A. F.
*Morris, William J.
Morris, William J.
Morse, A. C.
*Mosle, A. Henry
Moss, J. B.
Mudge, E. W.
Murray, C. B.
Murray, W. P.
Mustin, J. G.

N

Nash, Albert L.
Nash, H. P.
Neal, Albert D.
Neale, John C.
Neckerman, W. M.
Neeland, M. A.
*Newhall, M. L.
Ney, Robert W.
Nibecker, K.
*Nichols, John
*Nichols, K. A.
Niedringhaus, Geo. W.
Norris, F. E.
Norris, G. L.
Norton, D. Z.
Nullmeyer, Frank H.

O

Ohl, E. N.
O'Bleness, H. M.
*O'Neill, J. L.
*Otis, C. A.

P

*Pack, Albert
*Page, Rufus W.
*Painter, C.
Palmer, Wm. P.
Palmer, William R.
Pargny, E. W.
Parks, Frank E.
Patterson, P. C.
*Pattison, Melvin
*Pattison, W. M.
Patton, Albert
Peck, C. J.
Peckitt, Leonard
Penton, John A.
Perry, John E.
Peters, Richard, Jr.
*Peterson, Gustav
Petinot, N. G.
*Pettee, Robert O.
Pheneger, B. E.
Pickands, H. S.
Pierce, Talbot E.
Pilling, W. S.
Pinkerton, Andrew
*Piper, A. E.
Pope, C. E.
*Pope, H. F.
*Prentiss, F. L.

Q

Quarrie, B. D.

R

Rachals, Walter
Radford, Robert
Ralston, J. S.
Ramsburg, C. J.
*Ramsey, W. H.
Rand, Charles F.
Rathbone, R. L.
Raymond, H. A.
*Reed, W. E.
Reese, J. N.
Reis, John
Replogle, J. Leonard
*Rhadier, J. H. D.
Richards, F. B.
*Richardson, R. R.
Rider, R. S.
Robbins, M. C.
Roberts, Frank C.
*Roberts, Jas.
Robinson, C. R.
Robinson, C. S.
Robinson, T. W.
Roby, L. A.
*Roby, F. M.
*Rockhill, H. C.
Rogers, E. D.
Rogers, W. H.
Rogers, William S.
Root, Willis J.
Ross, Lewis P.
*Ross, W. G.
Rowe, Wallace H.
Rownd, H. L.
Ruiloba, J. A.
Runyon, W. C.
Russell, John R.
Rust, E. G.
Rust, E. Marshall
Rust, H. B.
Rust, R. R.
Rust, S. Murray
Rust, W. F.
Rys, C. F. W.

S

St. Clair, G. A.
*Sawhill, R. V.
Schiller, William B.

Schleiter, W. F.
Schmidt, J. C.
*Seely, F. D.
*Selmi, L.
*Severance, J. L.
Sheadle, J. H.
Sherer, J. N.
Sheridan, R. B.
Sherman, M. H.
*Sherwin, John
Shiras, MacGilvray
Short, George W.
Sias, J. M.
*Siebert, H. S.
Siebert, W. P.
*Simonds, A. T.
Skewis, Joseph R., Jr.
Smart, Geo.
*Smith, B. S.
Smith, C. C.
*Smith, F. B.
Smith, Floyd K.
Smith, J. C.
Smith, James W.
Smith, S. L.
*Smyth, W. B.
Speer, Joseph T.
Speller, F. N.
*Spitz, Frank
Sprague, E. M.
*Sproat, Roger H.
*Squire, Andrew
*Stafford, Sam'l
Stanton, W. A.
Stebbins, H. S.
Steese, R. C.
Steinen, F. W.
Stephenson, B. S.
Stevenson, Malcolm R.
Stewart, Scott
Stoughton, Edwin R.
*Sullivan, J. J.
Suppes, Max M.
*Sutherland, J. D.
Swartz, A. H.
*Sweeney, A. J.
Sweetser, Ralph H.
Sykes, Fred W.
Sykes, W.

T

*Taylor, H. R.
Taylor, Knox
Taylor, W. A.
Thomas, E. P.
Thomas, C. S.
Thomas, E. W.
Thomas, L. E.
Thomas, T. E.
Thomas, W. A.
Thompson, A. W.
*Thompson, H. L.
*Thomson, A. W.
Thorp, George G.
Tod, Fred
Topping, John A.
Topping, W. B.
Townsend, H. E.
Townsend, J. F.
*Treadwell, M. H.
Tripp, Chester D.
*Tucker, S. W.

U

Underwood, L. H.

V

Vallat, B. W.
Vogel, F. A.
Vogt, C. A.
Vollman, J. C.
Vreeland, George W.

W

Waddell, J. D.
Wade, J. H.
*Walker, Clarence
Walker, J. C.
Walker, W. R.
*Wallace, D. F.
Wallace, James C.
*Wallace, J. L.
Wallingford, B. A., Jr.
Ward, D. L.
*Warner, G. H.
Waterman, Fred W.
Watson, W. E.
Weatherwax, H. B.
Weaver, H. B.
Webb, F. J.
Weir, D. M.
Weir, E. T.
Wellman, S. T.
Wells, Daniel
West, J. G., Jr.
Westfall, H. D.
*Wharton, S. G.
Wheeldon, John
Wheeler, Seymour
Whittemore, E. L.
*White, Rollin
*White, W. T.
*Whiting, A. T.
*Whitworth, E. A.
Whyte, George S.
Wick, H. B.
*Wick, M. A.
*Wicks, J. C.
Wilkin, John T.
Williams, E. H.
*Williams, E. M .
Williams, H. D.
*Williams, Roy A.
Williams, J. C.
Williams, W. S.
*Wilson, Henry M.
Wilson, James W.
Wilson, Parker F.
Wisener, G. E.
*Wood, Chas. C.
Wood, Chas. L.
*Wood, H., Jr.
Woods, Leonard G.
*Woodworth, F. T.
Wooldridge, William J.
*Word, E. W.
Wright, Wm. H.
*Wright, S. D.

Y

Young, A. G.

Z

Zehnder, C. H.
Zehnder, E. M.

*Guests